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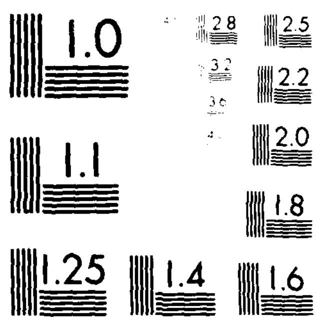

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FINAL REPORT

Fresh-Water Mussels (Mollusca: Bivalvia: Unionidae) of the Upper Mississippi River: Observations at Selected Sites Within the 9-Foot Channel Navigation Project on Behalf of the United States Army Corps of Engineers

June 1978

THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA · NINETEENTH AND THE PARKWAY · PHILADELPHIA, PA. 19103

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A survey of freshwater mussels of the Upper Mississippi River drainage was conducted during the summer and autumn of 1977. Over 8,000 living specimens were gathered and examined during surveillance of more than 40 actual and/or potentail dredging sites in the Minnesota and St. Croix Rivers and in almost 20 Upper Mississippi River pools.

Dredging and associated activities to maintain the 9-foot navigation channel has caused local mortality of mussels, including endangered species.

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There are other factors having far greater adverse impact, including wastes from the cities of Minneapolis and St. Paul, agricultural runoff, impoundment of the Upper Mississippi River and encroachment by Corbicula fluminea, the Asiatic Clam.

The outlook for a continuing ecosystematic and commerical mussel resource appear to be good. Even certain endangered species (e.g. Lampsilis higginsi) are likely to survive if appropriate measures are taken.

FINAL REPORT

Fresh-Water Mussels (Mollusca: Bivalvia: Unionidae) of the Upper Mississippi River: Observations at Selected Sites within the 9-Foot Channel Navigation Project on Behalf of the United States Army Corps of Engineers

Samuel L. H. Fuller

No. 78-33

The Academy of Natural Sciences of Philadelphia
Division of Limnology and Ecology

19th and the Parkway Philadelphia, Pa. 19103

June 16, 1978

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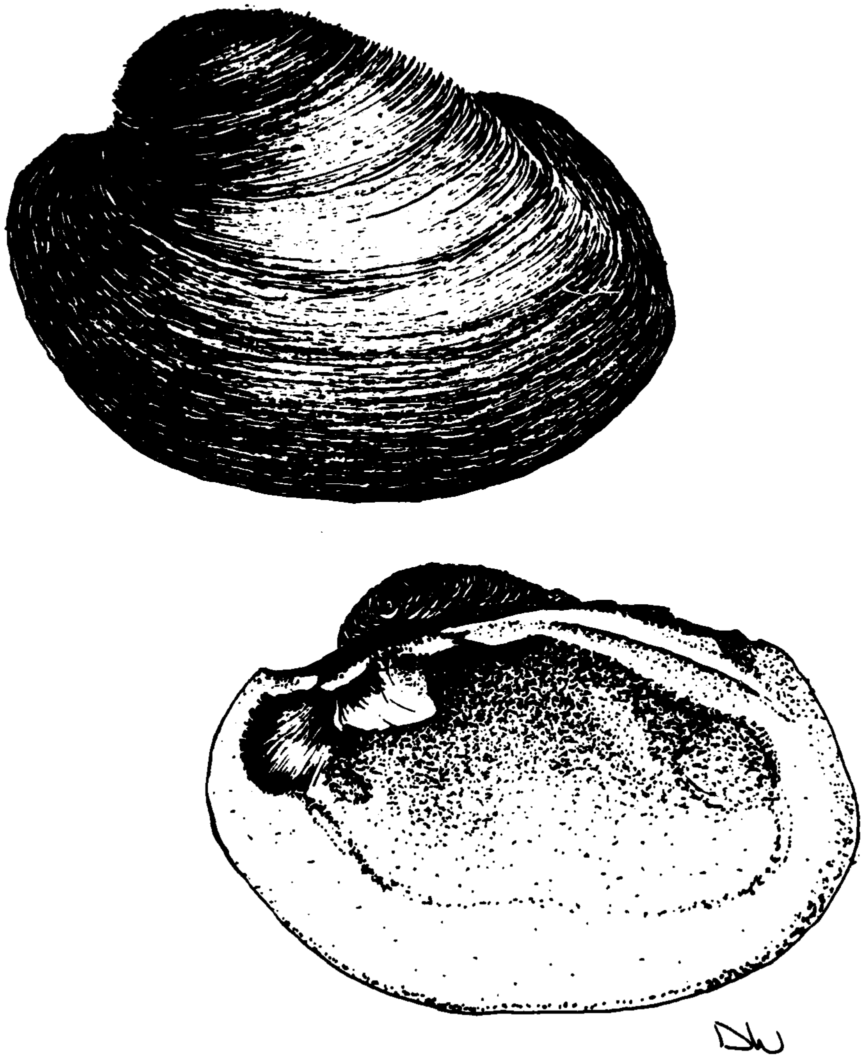

Higgins' Eye

Lampsilis higginsi (Lea)

ABSTRACT

On behalf of the St. Paul and Rock Island Districts of the United States Army Corps of Engineers, the Academy of Natural Sciences of Philadelphia conducted a survey of fresh-water mussels (Mollusca:Bivalvia:Unionidae) of the Upper Mississippi River drainage during the summer and autumn of 1977. Over 8,000 living specimens were gathered and examined during surveillance of more than 40 actual and/or potential dredging Sites in the Minnesota and St.Croix Rivers and in almost 20 Upper Mississippi River Pools. Historical and recent data were collected as complements to the Academy's 1977 information about Upper Mississippi mussels. A history of the success or decline of each species-group mussel taxon is provided, plus notes on its ecology and nomenclature (both Latin and vernacular).

For about 40 years the Corps of Engineers has conducted dredging and associated activities in order to maintain the Upper Mississippi River 9-foot navigation channel. This maintenance has caused local mortality of mussels, including Endangered species, but improved planning promises to reduce or eliminate most of these problems. Furthermore, there are factors having far greater adverse impact upon mussels: these include wastes from the cities of Minneapolis and St. Paul, Minnesota; agricultural runoff, notably what is introduced by the Minnesota and Des Moines Rivers; impoundment of the Upper Mississippi River as a series of "river-lakes" or Pools; bedload from the Chippewa River; and encroachment by *Corbicula fluminea*, the Asiatic Clam.

The quantities of many mussel species have been locally or regionally reduced during recent decades, whereas a few appear to have increased their numbers and geographic ranges. However, the representation of most mussel species relative to one another has not changed greatly in the last 50 years or so. The ability of most species to reproduce themselves is certain. In view of the plentiful adults and juveniles of many taxa, the outlook for a continuing ecosystematic and commercial mussel resource appears to be good. Even certain species considered legally Endangered (e.g., *Lampsilis higginsi*) are likely to survive if appropriate measures are taken.

TABLE OF CONTENTS

INTRODUCTION

At the request of the United States Army Corps of Engineers, the Division of Limnology and Ecology of the Academy of Natural Sciences of Philadelphia has conducted a study of the geographic and ecological distributions of freshwater mussels (Mollusca: Bivalvia: Unionidae) in the Upper Mississippi River drainage basin.

The Corps is charged with maintaining the 9-foot navigation channel in the Mississippi River and some of its tributaries. This maintenance requires extensive dredging in order to remove sediments that accumulate in the channel. Dredging is known to pose certain threats to aquatic organisms. There has been a well established community of freshwater mussels in the Upper Mississippi River drainage basin, as proven by historical and contemporary scientific records and by the success of a commercial mussel fishery. The greatly reduced abundance of some of these species was officially recognized in 1976 when, under the provisions of Public Law 93-205 ("The Endangered Species Act of 1973"), the Department of the Interior declared Endangered several mussel taxa recorded from the Upper Mississippi River. The Corps of Engineers authorized the present study in order to determine and describe any possible relationship between the status of mussel populations in the Upper Mississippi River drainage basin and dredging and associated activities conducted by the Corps of Engineers in order to maintain the 9-foot navigation channel.

The project design was developed through cooperation of the Corps, the United States Fish and Wildlife Service, the Departments of Natural Resources of Wisconsin and Minnesota, and the Academy. The study area included navigable portions of the lower Minnesota and St. Croix Rivers and of the Upper Mississippi River from the head of navigation (in the Twin Cities) to the vicinity of Canton, Missouri. Over 40 Sites were examined in the field during a study period exte`ing from mid-July through mid-November 1977. All Sites had an extensive history of dredging and/or were scheduled for future dredging. Some Sites were selected additionally on the basis of the suspected presence of one or more Endangered mussel species. At each Site, the mussel community was sampled, and various observations were made regarding the physical and biological condition of the Site, the condition of the mussel community, and the possible effects of dredging on this community.

In addition to this field study, a literature search was conducted in order to discover historical presence/absence

records of mussels in relevant Sites, Pools, and/or rivers. A comparison of the historical record with the Academy's 1977 field observations on mussel communities permits an assessment of causes of the decline of the Upper Mississippi River mussel fauna, including possible adverse impact by Corps dredging activities.

The bibliography includes references cited in this report and other sources used during the course of this study.

The appendices present information stipulated in the Scope of Work and certain additional information (Appendices [illegible] and parts of A and C).

Appendix A consists of a systematic "master list" of (presumably living) Upper Mississippi drainage species-group mussel taxa, a discussion of their Latin synonyms, and a list of their vernacular names and synonyms. The "master list" has been compiled from numerous sources (notably the Academy crew's 1977 field experience, Coker (1919), Grier and Mueller (1922-1923), van der Schalie and van der Schalie (1950), and Perry (1978)). The classification employed in the master list is based primarily on biochemically and morphologically derived modifications of the system devised by Ortmann (1910b, 1911, 1912, 1919) and was developed by two Academy researchers (George M. Davis and Samuel L. H. Fuller).

Appendix B contains Site-specific information about the Academy's mussel sampling: Site locations, date(s) of collection, field personnel, sampling technique(s), approximate riverbed area surveyed, and numbers of positive and negative brail runs. Procedures used and types of data collected were coordinated between the Academy's field work and the survey of commercially valuable mussel populations in Wisconsin waters of the Upper Mississippi River that was concurrently conducted by the Wisconsin Department of Natural Resources (WDNR). Finally, Appendix B includes maps of certain mussel beds.

Appendix C presents the results of the Academy's mussel sampling, as well as recent and historical presence/absence records gathered as part of a literature search. This search was not limited to the published literature; it included extensive use of unpublished reports (e.g., consultants' reports) that were generously provided by various individuals, government agencies, and academic institutions in the upper Mississippi basin. These data provide a rather thorough record of the mussel fauna's progress through about the past [illegible]0 years in the study area as a whole, at each Site, and in each Pool (or pre-impoundment reach) and/or river.

Finally, information is provided about the larval

hosts of mussels (in Appendix D).

A section devoted to Additions and Corrections concludes the report.

The important role of aquatic vegetation in mussel biology is occasionally addressed in the accounts of Sites and taxa in the text. However, no extensive data were recorded, largely because of the late start of the field work and the increasing senescence of the vegetation as the season progressed.

Similarly, attempts to record precise water depth measurements were abandoned after it became evident that changing river stages meant that such data provided an invalid basis for comparisons between and among Sites and/or taxa. However, the issue of depth is addressed in general terms in many of the natural histories below (see Results and Discussion: Species-Group Mussel Taxa).

The Academy was unable to settle the old question about when mussels enter winter dormancy and cease to respond to the brail. At about the Nearctic latitude of southern Iowa the answer seems to be that the critical temperature lies in the range of 50°F through 55°F. This tentative determination is based in part on observations by Thomas M. Freitag (personal communication, Rock Island District, Corps of Engineers).

ACKNOWLEDGMENTS

The design of this study was conceptualized by representatives of the United States Army Corps of Engineers (CoE), the United States Fish and Wildlife Service (FWS), the Wisconsin Department of Natural Resources (WDNR), and the Academy of Natural Sciences of Philadelphia (ANSP).

The field work was performed principally by ANSP personnel Edward Ambrogio, Daniel J. Bereza, Mary Lue B. Fuller, Samuel L. H. Fuller (Project Leader and Principal Investigator), and Roger L. Thomas. Use of the R/V *Izaak Walton* was arranged through Thomas O. Claflin, Steven D. Swanson, and A. Vincent Weber of the University of Wisconsin at La Crosse; the help of Dr. Claflin (Director, River Studies Center) was of essential value to many aspects of this project. All persons who assisted the Academy crew with collecting mussels in the field are listed in Exhibit B, but of special value were WDNR staff members Terry Larsen and Timothy Larson, plus Corpsmen Robert C. Halvorsen, Llaird B. Hunter, Richard J. Jones, Peter Knight, Larry L. Protsman, Donald L. Rudd, and Robert J. Whiting. The Academy crew received unfailing assistance at the Locks and Dams, notably from the Lockmasters and their staffs at Locks and Dams 3, 4, 14, and 19. Private citizens, most of whose names are unknown to the Principal Investigator, were regularly of great assistance; Edward Passe (Wabasha, Minnesota), Dwayne Thornberg (Prairie du Chien, Wisconsin), and Mr. and Mrs. Donald L. Rudd (Keokuk, Iowa) deserve special acknowledgment.

Janet Sheridan conducted the literature search. Her requests for information were honored by a host of representatives, unnamed here, of Mississippi River basin colleges, universities, and government agencies. The Principal Investigator wrote this report, which was edited principally by Daniel H. Snyder and refereed by James Engels and John Wolflin (FWS); James Holser (WDNR); Thomas M. Freitag, Donald Potter, II, and Robert J. Whiting (CoE); and James L. Peterson and John W. Sherman (ANSP). The typing was performed by Cheryl A. Brooks, Lucy Daria, Mary Lue B. Fuller, Patricia Ferguson, James L. Gollin, Marcia Mintess, Janet L. Morrison, Eleanor L. Thomas, and the Kelly and Jacki Carroll Services of Danbury, Connecticut. Margaret Henderson proofread the final report. Eleanor L. Thomas oversaw generation of the Draft Preliminary and Final Reports. Diane Whiting created the drawings for the Frontispiece.

Important in many parts of the report is information provided by Francis W. Collins, Thomas M. Freitag, and Robert J. Whiting (CoE), plus Daniel J. Bereza (ANSP), Lydia Halversen (Wabasha, Minnesota), Marian E. Havlik (La Crosse, Wisconsin), Ronald Oesch (St. Louis, Missouri), Edward W. Perry (FWS), David H. Stansbery (Ohio State University), and Malcolm F. Vidrine(University of Southwestern Louisiana).

Finally, the Principal Investigator recognizes the gentlemanly cooperation received from his *egotes alteri*, Richard F. Berry (then CoE, now FWS) and Robert F. Post (CoE), who shared duty as the Corps' Contracting Officer's Authorized Representative (COAR).

Should this document warrant dedication to specific persons, certain names mentioned above are especially deserving: Claflin, Havlik, Oesch, Perry, Rudd, Sheridan, Snyder, Swanson, and Eleanor Thomas.

Any deserving persons absent from consideration above were omitted inadvertently, at the fault of the Principal Investigator, who accepts responsibility for all other shortcomings of this document.

METHODS AND PROCEDURES

The field study was conducted from mid-July through mid-November 1977, in the portions of the Upper Mississippi River basin described in the Introduction. A three-man crew worked the entire study period and was joined for varying lengths of time by several other workers and numerous observers.

The principal craft used were the R/V *Izaak Walton*, a 55-foot houseboat equipped as a research vessel (R/V), and a 16-foot johnboat with a 25-hp Evinrude outboard motor.*

Brailing (from the johnboat) was the most important method used for collecting mussels (in water depths up to and including about 30 ft). The brail is a controversial device in terms of design, efficacy, and environmental damage (see, e.g., Coker, 1919, and Krumholz et al., 1970). The negotiated scope of work settled upon the brail, in spite of its disadvantages, because it maximizes the amount of mussel presence/absence data obtained from a Site (defined below) in a given amount of time while causing minor mussel mortality. Brailing was the only technique used in water too deep for scraping or pollywogging (defined below).

The Academy's brail is a 10-foot bar of 2 in by 3 in seasoned hardwood from which hang chains bearing numerous multiple hooks. The chains are 10 in long. The "hooks" are of the "Boepple type": straight wire tines tipped distally with balls of solder (see Coker, 1919, whose account of the construction, variations, and use of the mussel brail remains the classic). Several gauges of wire were used in order to avoid size-selectivity in mussel capture. The bar floats while the hooks graze the riverbed. As a hook passes between the open valves of a mussel, the animal clamps shut on it and is drawn from the riverbed by the movement of the boat and brail. The effectively peened hooks do not dislodge from between the valves except with great battering, as on an unevenly rocky streambed (see Coker, 1919).

The johnboat was slowly backed downstream, trailing the brail from its bow. This kept the collecting gear's towropes clear of the motor's propeller and minimized transmission of the motor's vibration through the ropes to the gear. A "brail run" consisted of towing the brail downstream for a five-minute interval, after which it was raised, and any mussels were removed.

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* An Evinrude was chosen because of its exceptional dependability when used in reverse gear and at low speeds, as required by the brailing technique described later.

Sampling techniques other than brailing were used as needed. Mussels in water up to about five feet deep were sometimes sampled with a Needham scraper, chiefly in an attempt to secure juveniles and young adults. Mussels in very shallow water (up to about 3 ft deep) were sometimes sampled by polly-wogging, in which the wading or swimming collector recovers mussels by hand. These shallow-water techniques were used whenever needed; in practice their use was rare, chiefly because few Sites included productive shallow-water areas in locations designated for surveying (see below). Where mussels of special interest, such as federally protected species, were discovered, the streambed was investigated by HOOKAH diving. This form of hard-hat diving permitted thorough local examination of the mussel community without damaging the animals.

As described in the Introduction, Sites were chosen on the basis of past and/or present dredging activity and suspected mussel presence. Unless otherwise specified by the Corps, the areal limits of a given Site consisted of both an Impact Zone and the one-mile reach immediately below it. The Impact Zone was the reach that included all potential dredge cuts and placement sites for dredged riverbed material. The Impact Zone's upper river mileage was that of the upper terminus of the uppermost dredge cut or placement site; its lower limit was the river mileage of the lower terminus of the lowermost dredge cut or placement site. Intensive sampling was conducted in the Impact Zone and for a 1/4-mile reach below it, because of the possibility that material disturbed during dredging might migrate that far. Cursory sampling was stipulated for an additional 3/4-mile reach immediately downstream, but sampling in that reach was always intensive if the mussel fauna there was well developed.

Within the areal limits of a Site, the Academy surveyed for mussels in locations potentially subject to direct or indirect impact from channel maintenance dredging. Such locations usually consisted of the main channel, main channel borders, and major side channels.

The length of time required to sample a Site by any technique or combination of techniques varied widely according to the abundance and complexity of the mussel community and the length of the Impact Zone.

Appendix B presents several kinds of information about each Site, such as geographical location. Sites are treated further in the Results and Discussion.

All mussel samples were processed daily in the field laboratory, usually the *Izaak Walton* itself. Mussels were opened and searched for evidence of disease. Tissue samples

were removed and frozen for subsequent biochemical investigations at the Academy (this type of research is reflected by the classification employed in Appendix A). The shells were cleaned of remaining tissue and identified in the field. Some individuals were preserved whole by a process (see Fuller, 1974a) developed to maintain in lifelike aspect morphological features involved in taxonomic determinations. All mussels were shipped to the Academy to be catalogued into the collections of the Department of Malacology.

RESULTS AND DISCUSSION

This section of the report is subdivided into two portions, Sites and Taxa. Discussion of a given Site or species-group mussel taxon sometimes offers an opportunity for consideration of a theme or topic of general relevance. The locations of such treatments are identified in the remarks introducing Sites or Taxa.

Sites

The discussion of each Site includes some or all of the following topics: water depth, streambed type, streambed particle size distribution, collecting technique, dredging history, submerged aquatic vegetation, dead shells (especially on dredged material placement sites), sampling effort, abundances of taxa and/or individuals relative to one another, and sources of unfavorable environmental impact.

According to the extent and nature of the available relevant information, the organization of the following discussions varies somewhat. For example, two or more Sites in a given river or Pool may be treated as a unit because they are so similar, whereas most Sites receive individual attention. In the latter case, if the Sites nevertheless have characteristics in common, these are mentioned (or discussed) previously, under the heading of the river or Pool to which the Sites belong.

The heading of the discussion of a given river, Pool, or Site includes reference to one or two Exhibits. The Exhibit numbers identify locations of additional data (on Site locality, field personnel, mussel community composition, etc.) in Appendices B and/or C.

Each Site has received a vernacular name, usually one traditionally employed by the Corps. However, choice of name was sometimes left to the Principal Investigator's discretion.

Discussions of the following topics occur under the indicated headings.

Minnesota River--effects of agricultural runoff

St. Croix River (Hudson Site)--mussel "migration"; interpretation of shells found on "spoil banks"; substrates more and less favored by mussels; the "*Corbicula* problem"

Upper Mississippi River--Sites given only cursory surveillance in 1977

Pool 8--treatment of Ellis survey data by the van der Schalies (1950); the Endangered Species Act of 1973

Craigel Island--deep-water mussel beds; adverse point sources

Hog Island--backwaters as nursery grounds

Minnesota River (Exhibit 50)

Below Cargill (Exhibit 4)
Petersons Bar (Exhibit 4)
Above Route I-35W Bridge (Exhibit 4)

The three Sites are discussed as a unit because of their contiguity and environmental similarity.

The Corps has conducted very little channel maintenance dredging in the Minnesota River, most of it occurring during the last decade. Dredging has been both infrequent and very localized, restricted to six areas, two of which are within the reach surveyed by the Academy. This history (USACE, 1974b), however, cannot have been very important to mussels - and certainly is not now - because the fauna has been devastated, as discussed below.

Mussels probably are extinct in the lower Minnesota River and have been so for many years. Not even recently dead gapers were found; all observed material was long dead or subfossil. To what extent these phenomena pertain throughout the river is uncertain because the upper Minnesota has not been thoroughly examined of late years, but they definitely pertain from Port Cargill to confluence with the Mississippi. This entire reach was brailed wherever gravel bars were suspected because of nearby gravel riverbanks.

It is clear that this river once supported a strong naiad fauna. From Dawley's (1947) lists of Minnesota drainage mussels can be inferred 32 presently acceptable species-group taxa. At the Sites the Academy investigators observed many of these, often so abundant that the banks consisted almost entirely of shell.

The probable cause of this destruction is agricultural runoff. Very heavy organic enrichment, emanating from manure and other fertilizers, is doubtless responsible for the benthic filamentous green algae that sometimes became entwined in the brail and for the miles-long blooms of diatoms and bluegreen algae observed at water's edge. Organic loading, however, is probably not wholly responsible for the naiad extirpation. Biocides are suspected as a complementary agent.

Regardless of the identities of the lethal factors, they seem to continue at levels sufficiently high to prohibit recolonization from refugial populations higher up the Minnesota sub-basin, such as the extant (though damaged) fauna in the Blue Earth River (see Chelberg, 1974, 1978). This means that the Minnesota River, acting as a point source where it enters the Mississippi in upper Pool 2, must exert a powerful adverse

influence. Pollutants from this source, plus the Twin Cities' contributions, continue to damage mussels, in at least Pools 2 and 3.

St. Croix River (Exhibit 51)

Hudson RR Bridge (Exhibits 5 and 52)

Because this Site is the only one on the St. Croix that was surveyed by the Academy, discussions of the naiad faunas of Hudson and of this river are undertaken together.

Using Dawley's (1947) lists of mussel species of Lake St. Croix, the St. Croix River, and the St. Croix River drainage as reference points, one concludes that the Hudson Site fauna persists in excellent health as measured by both number and variety of species. Dawley's totals are 16, 25, and 29 species, respectively. This survey's total is 23, which compares favorably with any of those (each of which has been adjusted according to recent taxonomic concepts and is lower than Dawley's original figure). The 1977 total includes what appear to be three new records for the entire St. Croix drainage: *Quadrula metanevra*, *Q. quadrula*, and *Elliptio crassidens*. Also, this total increases the Lake St. Croix list by about 50%, an extraordinary advance. In terms of the variety of its naiad fauna, Lake St. Croix appears not to have declined, in spite of the present era of general environmental degradation.

Most of the Academy's positive Hudson data were derived from investigations of a seam of mussels that proceeds downriver along the Minnesota shore for several hundred meters below the Hudson RR Bridge. In terms of quantity and frequency, Corps dredging in the vicinity of the Hudson Site, including the seam just mentioned, appears to have been minor, certainly in comparison to such activity elsewhere in the St. Paul District (USACE, 1974b). Indeed, the "RR bridge seam" is of such vigor that to suppose serious nearby disturbance appears unwarranted. For example, Academy brailing and HOOKAH divers discovered two *Lampsilis higginsi*, a male and a gravid female. This Endangered species was not only surviving, but also accomplishing fertilization, the first step in reproduction, on the border of the main channel and within a few meters of an area that has been dredged several times, most recently and extensively in 1970.

It is highly unlikely that these two animals migrated to their points of capture during the seven years since 1970. First, both individuals were far more than seven years old. Second, adult mussels do not move great distances (unless

stimulated by heat, for example) and rarely move at all (see Fuller, 1974b), especially in stable riverbed (discussed below) such as that occurring below the RR bridge. Third, as discussed below, there is no other population at this Site from which the two Higgins' Eye could have migrated.

The implication is that sediment migration caused by dredging has not been a problem here. Similarly, inspection of old dredged material at this Site revealed few dead shells. It is therefore apparent that the Corps' channel maintenance activities at Hudson have had little adverse impact upon mussels.

(It should be emphasized that here and elsewhere in this report any mention of shell associated with dredged material refers to shells that are presumed to have been deposited during dredging. They should not be confused with shells that have been washed downstream and onto a deposit. Making the distinction is not easy in practice, unfortunately, so ascription of dead shell to Corps dredging will be claimed (below) only occasionally, in unequivocal instances.

Difficulty in distinguishing washed-in from indigenous material has further drawbacks. Bone and gaper records cannot usually be admitted to even the historical species list for the Site where the shells were found, although it is generally reasonable to consider them legitimate historical or recent records for the relevant reach or Pool.

Both dredge kill and wash-ins can be confused with additional categories of dead shell: mussels killed by beasts and by man. Muskrat and raccoon predation was occasionally in evidence in the study area, and individual humans still take mussels for bait, food, or pearls. In each of these cases, the evidence usually is small piles of recently killed shells. Dump shell from the old pearl button industry can usually be separated from other material because of the holes drilled in the shells where button blanks were removed.)

In sharp contrast to the RR bridge population, few mussels were found elsewhere at the Hudson Site. Presumably, the type of riverbed below the bridge (extending spottily along the Minnesota shore downstream to about the federal highway 12 bridge) provides the only prime mussel habitat in the Site. Diving revealed that the riverbed here is an admixture of mud, gravel, and small stones. Because it is stable, yet penetrable by infauna, this type of substrate strongly favors exploitation by mussels (Kaskie, 1971). The extensive beds of submerged vascular vegetation just below the RR bridge provided further stability; mussels, including juveniles and young adults, were exceptionally plentiful in that muddy area. In sandy places, however, mussels were very rare, and extensive

pollywogging was required in order to find the few individuals that were secured.

These observations bear out Kaskie's (1971) ranking of substrates in descending order of preference by mussels: "mud, fine gravel, gravel, sand, and sludge". Substrate approximating Kaskie's "sludge" (a combination of materials dominated by silt and fine sand) was seldom encountered at the Hudson Site except in the small-boat harbors, and mussels were not found in it. H. M. Paulson (personal communication) contended that Threeridge, *Amblema plicata,* can still be found on the harbor floor at the St. Croix Marina, but the Academy was unable to corroborate this.

Although optimal habitat was limited, a diversified mussel community was present at the Hudson Site, as already intimated. As is often the case, most of the 23 species were uncommon or even very rare, and the fauna was dominated by *Amblema plicata,* whose 266 individuals comprised 48.72% of the 546 that were found. Domination by Threeridge is a pattern that was to be encountered throughout the study area. The next to the most common species was *Fusconaia flava* (13.19%), which was proportionally better represented than at many Sites. *Elliptio dilatata* accounted for 6.78% of the material. Hudson is one of only two Sites where this species was common (Hay Point Bank Repair in Pool 10 is the other). Hudson was the only Site where *Lampsilis radiata siliquoidea* was common and one of the few where *Lasmigona complanata* (even at only 1.28%) was at all well represented.

Additional observations further evidenced the excellence of the Hudson Site naiad fauna. There were several year-classes among the juveniles recovered byssally attached to the brail and collected by hand in weed beds. Very difficult to secure by ordinary means, juveniles comprised 1.65% of the catch and represented four species. The one juvenile *Fusconaia flava* was among the few found in the entire study area. Good year-class representation among adults was common to this and other species. One readily infers that reproduction *and* recruitment occur at Hudson.

However, not all is potentially well with this community. On 8 August 1977 living *Corbicula fluminea* were discovered at the Hudson Site. This may be the first record of the Asiatic Clam in the St. Croix River drainage. The appearance of this exotic competitor for benthic space is to the disadvantage of native mussels; for example, there is evidence that *Corbicula fluminea* can dislodge mussels from the streambed, thus uprooting them to their eventual death (Fuller and Richardson, 1977). If this creature becomes established among the railroad bridge population, the Hudson Site mussel fauna

will probably become greatly simplified after a few years.

On the other hand, the Asiatic Clam is an arenophile (Filice, 1958); correspondingly, it was found only in sand at Hudson. As noted above, sand is unfavorable to mussels and is minimal among the railroad bridge population. It is, then, conceivable that *Corbicula fluminea* may not dominate that mussel assemblage, after all. The need for continued observation is obvious.

The "*Corbicula* problem" has achieved a deserved notoriety during recent years. The "*Corbicula* story" in the Nearctic region is a lengthy one, and even a synopsis is extralimital to this report. Investigators are advised to turn to eclectic works, such as Sinclair (1971). There are two excellent and ongoing sources of information about the Asiatic Clam in America: *The Nautilus*, edited by R. Tucker Abbott, Delaware Museum of Natural History, Greenville and *Corbicula Newsletter*, edited by J. Mattice and L. S. Tilly, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

<u>Upper Mississippi River</u> (Exhibit 53)

In the definitive fashion stipulated by the Scope of Work (see Methods and Procedures), the Academy studied 42 Sites in the Upper Mississippi River, but the total surveillance that was given this part of the study area is somewhat more extensive.

An at least nominal Site, Above and Below Lowry Avenue Bridge in the Upper St. Anthony Pool, was effectively included in the other two Sites in that Pool, Below SOO Line RR Bridge and Above and Below Broadway Avenue and Plymouth Avenue Bridges.

The coverage of Hay Point Bank Repair, a Site in Pool 10, included much of the Opposite Harpers Ferry Site, which was otherwise not examined by the Academy in 1977.

Also in Pool 10, brailing was conducted in the East Channel of the Mississippi at Prairie du Chien, Crawford County, Wisconsin. The species records obtained are given in Exhibit 81 and are included among the cumulative data for Pool 10 (Exhibit 79), the Upper Mississippi River (Exhibit 53), and the Study Area (Exhibit 49). However, this sampling point neither was treated as a formal Site in the field nor is discussed as such in this report.

Boulangers Bend, a Site in Pool 2 above the Nininger Site, received cursory treatment sufficient to demonstrate the naiad devastation that is characteristic of that Pool.

Prior to initiation of the major field effort in July, the Academy had cursorily surveyed 10 additional Sites during late May. The results were reported by Fuller (1977a). Some of these data reappear as recent (R) records for the relevant Pools in the corresponding Exhibits of this report. These Sites are Pepin Small Boat Harbor, Reads Landing, and Crats Island (all in Pool 4); Fisher Island (Pool 5); Lock and Dam 5 (Pool 5A); Homer (Pool 6); and Lock and Dam 6, Winters Landing, Dakota, and Dresbach (all in Pool 7).

Pepin Small Boat Harbor is located on Lake Pepin at Pepin, Pepin County, Wisconsin.

Reads Landing was resurveyed for the present report.

Crats Island lies just above the Teepeeota Point Site that is reported below. The Ellis survey collected here (van der Schalie and van der Schalie, 1950).

Fisher Island was resurveyed as part of the Weaver Bottom Complex Site that is reported below.

Brailing was conducted only *below* Lock and Dam 5; therefore, this Site is referred to Pool 5A.

The Homer Site is at and off Homer, Winona County, Minnesota.

Lock and Dam 6 was surveyed only on the downstream side, and this Site must be ascribed to Pool 7.

Winters Landing, Dakota, and Dresbach are all in Winona County, Minnesota. The Ellis survey worked near Dakota (the van der Schalies, 1950).

Historical, recent, and current mussel records for the Upper Mississippi River are given in Exhibit 53. This fauna receives much discussion in the pages that follow. It has suffered in various ways since the Ellis survey in 1930 and 1931, but the degradation is not nearly so serious as the Principal Investigator had anticipated prior to the Academy's 1977 survey.

<u>Upper St. Anthony Falls (USAF) Pool</u> (Exhibit 54)

Below SOO Line RR Bridge (Exhibit 6)
(Above and Below Lowry Avenue Bridge)
Above and Below Broadway Avenue and Plymouth Avenue Bridges (Exhibit 7)

Surveillance of the first and third of these Sites

included the second, also, and amounted to coverage of almost the entire Pool. Because of the environmental and informational homogeneity of this reach, the Pool and its Sites are discussed as a unit.

Beginning in 1963, almost the entire length of the main channel in this Pool has been dredged at one time or another, but disposal of material occurred elsewhere (USACE, 1974b). Continued dredging and, at last, local disposal sites are contemplated. Such activities cannot have done, or be expected imminently to do, any damage to the Upper St. Anthony Falls Pool mussel fauna, simply because there evidently is none.

St. Anthony Falls formed a natural barrier to upstream penetration by mussels. Only a small fraction of the fauna of the lower reaches surmounted the Falls and gained the Mississippi headwaters (Dawley, 1947): *Actinonaias carinata, Ligumia recta, Lampsilis radiata siliquoidea, L. ovata ventricosa, Lasmigone compressa, Anodontoides ferussacianus, Anodonta imbecillis*, and *A. grandis*. Most of these have large numbers of glochidial hosts and thus doubtless have had plentiful opportunity for introduction above the Falls during their larval phase. Apparently the availability of glochidial hosts is not the only requirement for some species to extend their ranges into the area above the Falls. For example, *Amblema plicata*, which has many hosts and is environmentally very adaptable, has never been discovered there.

Lasmigona compressa and *Anodontoides ferussacianus* are characteristically small-stream species and are not likely ever to have inhabited the St. Anthony Falls Pools. A balance of only six mussel species, then, forms the core of the fauna that might be expected immediately above the Falls.

It is thus hardly surprising that so few dead shells were found in the Upper St. Anthony Falls Pool. What *is* surprising is that almost *no* mussel material could be found. Evidently, all naiades here were destroyed long ago. It is equally clear that recolonization in the foreseeable future will not occur. Water quality in this urbanized reach is doubtless prohibitive, and Ponar dredging revealed that much formerly suitable riverbed is now overlain by muck. It is a curious footnote to these remarks that the Academy has been unable to discover any historical mussel records that are definitely referable to this Pool. It may never have provided optimal naiad habitat, at least since thick settlement by European man began about a century ago, but a more probable explanation is that early local naturalists happened not to record mussel data appropriate to this report.

Lower St. Anthony Falls (LSAF) Pool (Exhibit 55)

The Corps has done minimal dredging in the Lower St. Anthony Falls Pool (USACE, 1974b). The Academy did not sample in this Pool and has been unable to locate relevant mussel records of any kind. It is highly probable that adverse conditions, past and present, noted in the Upper St. Anthony Falls Pool (just above) exist here, as well. Therefore, Corps dredging could hardly have done mussels any damage.

Pool 1 (Exhibit 56)

Above and Below Lake Street Bridge (Exhibit 8)
Below St. Paul Daymark 849.1 (Exhibit 9)
Lock and Dam 1 Upper Approach Construction (in part) (see Pool 2, below) (Exhibit 10)

Again because of their environmental and informational homogeneity, the Pool and its Sites are discussed as a unit.

Mussel records available to the Academy that are definitely identified with this Pool are limited to the species whose bones were discovered at the St. Paul Daymark Site. However, there can be no doubt that Pool 1 once shared the rich naiad fauna of the Upper Mississippi River below St. Anthony Falls. The quantity and the specific identities of current bones are sufficient proof.

As above the Falls, the fauna here has been devastated, though it is probable that the destruction concluded in Pool 1 at a later date than in the St. Anthony Pools. Some bones from this Pool are fresher than those from the latter, though all are of great age.

With increasing extent and frequency, the Corps has dredged in Pool 1 since before the Second World War. Now much of this reach is dredged during most years (USACE, 1974b). This is very intensive maintenance, but it has probably never done much if any damage to mussels, because apparently the fauna was essentially destroyed decades ago. Dredge sampling by the Academy revealed only sand and muck; these inhospitable substrates, plus other sources of ecological adversity (e.g., low dissolved oxygen, heavy metals, etc.), probably have been the norm for many years. Thus it appears that chances for foreseeable recolonization by mussels are remote.

Pool 2 (Exhibit 57)

In terms of its naiad fauna this reach has been and

is superior to those above. There are some historical records, a few current ones, and even one Site where living mussels were found during this project. (At the other Sites, however, there was only the devastation observed in the upper Pools.) Muck was the prevalent streambed in most areas. There were no submerged vascular vegetation and few bones, all very old. Probably the Twin Cities and the Minnesota River both negatively influence Pool 2.

The Corps' dredging this Pool began in 1937, but has been more sporadic in space and time than is the case upstream (USACE, 1974b). The finding of an extant mussel community suggests the possibility that the Corps may have disturbed freshwater mussels slightly - but only *very* slightly - more in Pool 2 than in those above.

Lock and Dam 1 Upper Approach Construction (in part)
(See Pool 1, above) (Exhibits 10 and 58)

There are several noteworthy points. First, this is a construction Site. Some dredging is doubtless involved, but it is not for channel maintenance.

Second, the construction is undertaken above the Locks and Dam, in Pool 1 (which see, above), but most of the investigative area lies below. For this reason and especially because living mussels were found there, this Site is discussed as though its entirety lay in Pool 2.

Third, mussels began in the dam tailrace and continued the length of the Site; none was found immediately below the locks, where the Corps has dredged in the past (USACE, 1974b). Whether there is a casual relationship between these two points is unknown and probably unknowable.

Fourth and unfortunately, this population shows poor condition. It is very sparse and sporadic, even though it extends (discontiguously and primarily along the left bank) for almost a mile. There was no evidence of recent recruitment, although fertilization is possible at this Site (*Strophitus undulatus* was gravid). On the other hand, that the gravel riverbed appeared clean of silt and that the water obviously was adequately oxygenated are encouraging.

Finally, one must wonder whether there are not other refugial populations thus far overlooked in the stricken uppermost Pools. If so, mussels could more rapidly reinvade those reaches if favorable water quality were restored to the Twin Cities vicinity.

Above and Below Smith Avenue ("High") Bridge (Exhibit 11)

This is the only Site in Pool 2 where bones were found. All were very old, and many were spoiled by exposure, so identification is dubious in some cases. These dead shells cannot necessarily be interpreted as indigenous to this Site (see Hudson RR Bridge, above). They are thus admitted only to the list for Pool 2 (Exhibit 57).

Robinsons Rocks (Exhibit 12)

No living or dead mussels were found at this Site, and apparently there are no previous records.

Boulanger Bend (cursory)

This Site was cursorily surveyed 21 July 1977 by the Principal Investigator with the aid of a St. Paul District launch and crew. No mussels, living or dead, were found, and apparently there are no previous records relevant to this Site.

Nininger (Exhibit 13)

No trace of mussels was found at this Site. Dawley (1947) provided some historical records (Exhibit 57).

Pool 3 (Exhibit 59)

The Academy examined no Sites in this Pool and has found no previous mussel records. This is curious because there is no reason to suppose that no mussels occupied this reach in the past.

Pool 4 (Exhibit 60)

Four Sites in this Pool were studied. They fall into two natural groups. The Lake City Site is on Lake Pepin, and the other three Sites lie below this lake in the reach whose upper terminus is at the confluence of the Chippewa River with the Upper Mississippi. In several respects, the characters of the two groups differ profoundly.

Almost the entire Upper Mississippi River mussel fauna, including the Endangered *Proptera capax* and *Lampsilis higginsi*, is known historically in Pool 4. However, only 19 species have been encountered recently, and only 12 were found alive in 1977. This remarkable decline is either real or an appearance caused by insufficient investigation.

A marginal commercial mussel fishery still exists in Lake Pepin, and some small beds have persisted (Jim S. Engel,

personal communication, St. Paul District, Corps of Engineers). Nevertheless, great abatement of clams and clamming has occurred since the heyday of the Lake Pepin Mucket, perhaps the greatest button shell of them all (see Coker, 1919). The phenomena behind Pepin's notoriety as a kind of catch basin for Twin Cities wastes surely are largely to blame. It is probable that faunistic decline is more real than apparent in this river-lake.

As a catch basin, however, Lake Pepin reduces adverse impact from the upper reaches upon the more riverine, lower portion of Pool 4 below the Chippewa River, just as the St. Croix River, entering this Pool at its head, has a diluting and thus favorable influence upon the adverse impact caused by Pool 3. One might, then, expect the modern mussel fauna to improve below Lake Pepin, although the negative influence of the Chippewa on Mississippi naiades in this area must be considered.

That Chippewa alluvium helped create Lake Pepin and influenced the Mississippi below is an established feature of the regional geologic record. At one time, this influence alone could not severely have limited mussel populations, because the Ellis survey records show that lower Pool 4 (Zone II of the van der Schalies, 1950) supported at least 29 species as late as 1930 and 1931. If the poor records of recent years are to be credited, in full or only in part, an additional adverse impact must have intervened at some point after Ellis' work. Could increased land use in the Chippewa watershed by an expanding human population have increased its alluvial contribution to the Mississippi? Is it only coincidence that extensive, increasing, and now almost perennial dredging by the Corps below Lake Pepin began in the mid-Thirties (USACE, 1974b)?

On the other hand, maintenance dredging and associated activities are confined chiefly to the main channel. This truism revives an earlier question, now expressed in a different way: are there extant mussel species in non-channel habitats of Pool 4 that were not investigated during the Academy project? Another type of investigation might demonstrate that the Pool 4 mussel fauna is, in fact, superior to what present evidence suggests.

In any case, the Upper Mississippi main channel in lower Pool 4 carries a substantial bedload, which is commonly attributed to the Chippewa. Dredging there is necessary for precisely the same reason that mussels cannot succeed, namely, heavy deposits of shifting sand. There can be no reasonable doubt that Corps maintenance in lower Pool 4 has killed many mussels, mainly juveniles, probably including some Endangered ones, but these individuals, isolated and

for the most part doomed by the shifting sand, could not have contributed to the populations of their respective species (see discussion of *Truncilla donaciformis*, below).

Lake City Small Boat Harbor Entrance (Exhibits 14 and 61)

Surveillance of a very limited area, about the harbor mouth, was required. In that respect this Site was unlike all others in this project. The Lake Pepin floor here was of the sand and muck commonly associated with marinas. It was very unproductive of mussels and harbored no legally protected species. Dredging here can hardly damage the naiad fauna. Note, finally, that this is not a channel maintenance Site.

Dawley (1947) gave "Lake City" mussel records (included in Exhibit 61 for the sake of historical perspective on the general area), but they cannot necessarily be referred to the Site. The Ellis survey worked just above Lake City, but the van der Schalies (1950) did not specify the findings; these records definitely should not be ascribed to the Site.

Reads Landing (Exhibit 15 and 62)

Commencing in 1934, the Corps dredged rather extensively at this Site during about one half of the years through 1972 (USACE, 1974b).

Represented by very few individuals each, only five living naiad species were found at this Site. This total probably is augmented by numerous others suspected of persisting at the Site and/or in the immediate vicinity on the basis of earlier records for this area (see Exhibit 62).

The Ellis survey worked this area, but the van der Schalies (1950) did not identify which species had been found.

Teepeeota Point (Exhibits 16 and 63)

At this Site in 1936 the Corps began extensive and almost perennial dredging, which persisted through 1971 (USACE, 1974b).

This Site exhibited a mussel assemblage only slightly less poor than the one from Reads Landing (compare Exhibits 62 and 63). The Academy has no relevant recent or historical records. Previous work at Crats Island upstream from the Site had produced nothing not found later at Teepeeota Point (Fuller, 1977a). The Ellis survey worked both areas, but the van der Schalies (1950) did not indicate which species

had been found at either.

Most of the Academy's adult material appeared to be remnant individuals from old beds associated with wingdams. Essential destruction of former beds would be an example of damage done by moving bedload in Pool 4 below the Chippewa.

Grand Encampment (Exhibits 17 and 64)

In 1937 at this Site the Corps began dredging that recurred a bit more frequently than every other year through 1970 (USACE, 1974b).

The 1977 mussel samples are very poor. Submerged vascular vegetation containing juvenile mussels was occasionally encountered. The Academy has found no additional relevant mussel records.

Pool 5 (Exhibit 65)

Pool 5 appears to have a richer mussel community, and to have experienced less dredging, than Pool 4. The inference is that moving bedload has here been the lesser problem to mussels *and* to the Corps.

An indicator of a superior mussel fauna in Pool 5 is downstream increasing values for the number of living animals per brail run.

Pool 4	
Reads Landing	0.2
Teepeeota Point	0.5
Grand Encampment	0.7
Pool 5	
West Newton	4.8
Weaver Bottom Complex	2.0

(There is no ready explanation for the anomalous figure for the Weaver Bottom Complex, but it *is* greater than any of the Pool 4 values.)

Evidence of a dredging program in Pool 5 that is comparatively favorable to mussels is that, although dredging persisted almost perennially after 1933 through 1971 and 1972 at West

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Evidence of a dredging program in Pool 5 that is comparatively favorable to mussels is that, although dredging persisted almost perennially after 1933 through 1971 and 1972 at West

Newton and Weaver Bottom Complex, respectively, the amount of dredging per year was less than at Pool 4 Sites.

Dennis Cin (personal communication, St. Paul District, Corps of Engineers) has pointed out that, at times of very high water, Pool 4 is permitted to drain, more or less unimpeded by Lock and Dam 4, into Pool 5. Bedload originating in the Chippewa River thus penetrates at least to the second Pool downstream from the Chippewa-Mississippi confluence. Mr. Cin added that the Zumbro River is believed *directly* to impact Pool 5 with migrating material. It seems that Pool 5 suffers somewhat less from sedimentation than does Pool 4, but neither Pool is any longer a wholly favorable environment for mussels, at least in its main channel portion.

The overwhelming domination of especially the Pool 5 data by juveniles, notably *Truncilla donaciformis* (whose discussion see, below), is the best available evidence (Exhibits 66 and 67) of the superiority of the Pool 5 mussel fauna. Ancillary evidence appears in comparisons among historical, recent, and current information: the respective totals are 15, 15, and 13 species (Exhibit 65). These figures suggest that the Pool 5 fauna has changed little during the past century. However, the total number of the species that have ever been found in this Pool is at least 25 (see Exhibit 65). At no one period of time, then, has more than two thirds of the cumulative fauna been found. If one assumes comparable sampling pressure and record-keeping during those periods, he must conclude that mussels have always been hard to find in Pool 5 (i.e., population sizes have been low). Perhaps the truth is not only that this Pool is not "any longer" (above) congenial to mussels, but also that it has never been so, at least in post-Columbian time.

The Lock and Dam 5 Culvert Construction Site scarcely figures in the preceding remarks because of its unique character (see below).

West Newton (Exhibits 18 and 66)

Viewed from upstream, the West Newton Site has the shape of a Y. The right (western) fork lies in the channel and consists only of an impact zone that terminates at the head of the Weaver Bottom Complex Site. The left (eastern) fork, however, does not end at the latitude of the beginning of the Weaver Site, but proceeds down Pomme de Terre (Belvidere) Slough for the additional mile below the impact zone that is specified in the Scope of Work (see Methods and Procedures, above). Now, near the upper end of this one-mile reach, Roebucks Run passes from the Weaver Site into Belvidere Slough. Data gained below this confluence could be ascribed to either Site, but West Newton has been chosen

because Belvidere Slough is much larger than Roebucks Run and is assumed to exert by far the greater influence below their confluence. Here is an example of the situation in which a reach that is by definition part of one Site is considered environmentally part of another. (This situation recurred at the Dallas Island Site in Pool 19 (below).) The unfamiliar reader can better follow this discussion with aid from USACE (1975).

Disposal bank sampling at West Newton revealed 10 naiad species. None is federally protected. None was represented by more than a few individuals. The latter point supports the conclusion that adult populations are sparce in Pool 5.

Weaver Bottom Complex (Exhibits 19 and 67)

Work at Fisher Island within the Complex had taken place in May 1977 (Fuller, 1977a), but added nothing novel to the September results for this Site.

Locks and Dam 5 Culvert Construction (in part) (See Pool 5A, below) (Exhibits 20 and 68)

This Site is unique in the Study Area, but not because part of it lies "in" Pool 5A (which see, below). It consists of limited areas above and below the Locks and Dam 5 earthen dam in the vicinity of a point where a culvert through the dam is proposed. The upper portion of the Site lies in Pool 5. Few mussels were found there. They were dominated by *Amblema plicata.* Significantly, in this area of stable riverbed more species were found than elsewhere in the Pool (Exhibits 66 and 67), where predominantly shifting sand floor was encountered.

Pool 5A (Exhibit 69)

The Academy twice (and cursorily) considered this Pool in 1977. The first instance is Fuller's (1977a) work in May, and the second is treated below. Some Wisconsin Department of Natural Resources records (Terry E. Larsen, personal communication) and Fuller's single one are all that the Academy has for Pool 5A. The former include current and recent data.

Lock and Dam 5 Culvert Construction (in part) (See Pool 5, above) (Exhibit 20)

Part of this Site lies in Pool 5 (which see, above). The part "in" Pool 5A actually is in a swamp on this Pool's floodplain near the eastern end of the Locks and Dam 5 earthen dam. No trace of mussels, living or dead, was found in this

swampy area.

Pool 6 (Exhibit 70)

The Academy studied no Sites in this Pool during the present project. However, there are some mussel data relevant to this Pool (see Exhibit 70). There appears to have been a decline in the number of mussel species inhabiting the Pool, but whether all available habitats have been recently explored is uncertain.

Pool 7 (Exhibit 71)

The Academy studied no Sites in this Pool during the present project. There are, however, numerous relevant data. These show a definite increase in the number of mussel species since the time of Dawley's (1947) list for "Dresbach" (in Pool 7), especially inasmuch as Marian E. Havlik's (personal communication) most "recent" records can be considered nearly or quite current for 1977. The apparent increase has been caused probably by greatly increased local interest in naiades (notably Havlik's). This suggests that recorded declines in certain other Pools are more apparent than real (Pools 4 and 6 are good examples). However, it is well to remember that the context of these remarks is number of species, not the overall well-being of the mussel community.

In addition to Finke's (1966) records for living *Lampsilis higginsi* in Pool 7 during 1965, M. E. Havlik (personal communication) has found this species' dead shells on dredged material banks. The Corps' responsibility for these deaths is indicated.

Pool 8 (Exhibit 72)

The Academy studied two Sites in this Pool, from which 15 living species of mussels were obtained; other current, some historical, and many recent records are available, as well. The current and recent species totals are very nearly the same, and both greatly exceed the sum of historical data. The discrepancy is surely caused by a dearth of relevant historical records. The Dawley (1947) study, for example, includes no records for Pool 8, and there are no studies that thoroughly examine this Pool's naiad fauna. The greatest loss of information is that, in synopsizing the results of the Ellis survey, the van der Schalies (1950) wrote from an essentially biogeographic point of view and provided no species lists (though a few notes) to accompany their list of Ellis' positive stations. In fact, there were only two (possibly

three) such stations in Pool 8 (and none in the Brownsville, Minnesota, area), but not any of the relevant species data, however few they may be, have been published. Moreover, the recent study by Coon et al. (1977) on the 1975 naiad fauna in Pools 8, 9, and 10 does not provide Pool-specific information.

The Coon study is intended to compare recent mussels of these three Pools with the very similar area ("Zones III and IV") of the van der Schalies' (1950) paper. Comparison of the results of Coon et al. to Ellis' shows a net loss of nine species from Pools 8, 9, and/or 10 during the intervening 40-odd years. The change is not surprising: for example, two of the nine (*Proptera capax* and *Lampsilis higginsi*) are now federally Endangered, and several of the others are very rare.

On the other hand, disappointment at this trend must be tempered somewhat by the evidence of the current fauna as revealed by combining the data in Exhibits 72, 75, and 79. In 1977, 28 mussel species were found alive in the Upper Mississippi River reach that consists of Pools 8, 9, and 10. Refusal (as in this report) to recognize *Lampsilis fallaciosa* 'Smith' Simpson as other than a form of *L. teres* means that the corresponding totals realized by Coon et al. (1977) and in Ellis' work are 21 and 29, respectively. Among the current 28 are several species not found by those workers, and Marian E. Havlik (personal communication) has found a few more in Pool 10 so recently that they are reasonable addenda to the 28. In terms of numbers of species, then, the modern fauna in this reach compares surprisingly well with that of nearly 50 years ago. Aside from the almost unarguable loss of a few species from these Pools in the meantime, the major changes that have occurred are matters of community structure. The more notable of these are considered in the species accounts below.

Above Brownsville (Exhibits 21 and 73)
Brownsville (Exhibits 22 and 74)

Being contiguous and environmentally similar, these two Sites are discussed essentially as a unit.

Commencing in 1940 and continuing through 1972, the Corps conducted moderately extensive dredging at either Site or both during most years (USACE, 1974b). The small numbers of dead shells on the historical dredged material banks indicated that the dredging had killed few mussels over the years. This inference is in accord with the character of the current fauna of this reach, which is rather species-poor and in 1977 consisted largely of juvenile *Carunculina parva*. As was true of so many Sites, the only common adults were *Amblema plicata*.

After the Academy had examined the Brownsville Site and found no trace of Endangered species, the Corp renewed dredging there. Subsequently, there was discovered on a fresh disposal bank a newly deceased mussel that Marian E. Havlik and David H. Stansbery (personal communication, Ohio State University), as well as the Principal Investigator, believe to be *Lampsilis higginsi*.

This document is not a proper place to debate the merits of the Endangered Species Act of 1973. Nevertheless, one conclusion that should be drawn from this incident is painfully clear: in spite of the undeniable good intentions of the Act, there still exists no device whereby the inappropriately trained person can rapidly learn to identify Upper Mississippi River mussels in order to prevent his getting into legal difficulties as a result of inadvertent "harassment" of an Endangered or Threatened species.

In its lower reach the Brownsville Site forks. The left (eastern) limb follows down the part of the main channel that is known as Cook Slough. The right limb quickly becomes unbrailable shallows among stump fields. This area supported much submerged vascular vegetation, which was characteristic of most slack water at both Sites.

Most of each Site, however, consisted of slightly deeper water over sand. The copious bedload of this reach has been responsible for the ongoing dredging history and, no doubt, for the paucity of mussels, especially adults (see *Truncilla donaciformis*, below).

Pool 9 (Exhibit 75)

The mussel data available from this Pool are sparce. The Academy examined a rather extensive area (4.6 RM), but gathered few data, and has found little relevant information in the literature. Finke (1966) and Perry (1978) provided some recent records; Ackerman (1976), none (see Pool 8, above).

The three Sites in this reach are contiguous and form, in effect, an unbroken, lengthy, essentially sandy chute, whose mussel fauna, completely dominated by *Amblema plicata*, is species- and individual-poor (Exhibits 76, 77, and 78). The unrewarding search of dredged material deposits was consistent with this. A large number of brail runs was expended on this "chute"; the majority was negative (Exhibits 23, 24, and 25).

Above Indian Camp Light (Exhibits 23 and 76)

This Site was dredged rather extensively in 1937, but had not been revisited through 1972 (USACE, 1974b).

The Site included upper Winneshiek Slough, where mussels were a bit more common along riprap above the Iowa state route 82 bridge than they were elsewhere in the Site.

Indian Camp Light (Exhibits 24 and 77)

The mussel fauna here was exceptionally poor. However, Corps dredging, only occasional from 1936 through 1972 (USACE, 1974b), could hardly have been at fault.

Lansing Upper Light (Exhibits 25 and 78)

Much longer than the Above Indian Camp Light Site, this one supported a mussel fauna that was proportionately even more impoverished.

Corp dredging took place almost the length of the Site in 1937, but thereafter through 1972 was intermittent and confined essentially to the 1977 impact zone (USACE, 1974b).

Pool 10 (Exhibit 79)

An only cursory visit to the vast East Channel beds at Prairie du Chien provided many current data about the mussels of this Pool, which are recorded in Exhibit 81 and figure in previous summations (Exhibits 49, 53, and 79). This was not a formal Site and is not discussed as such here. However, much of its information is considered elsewhere in this report. In addition, the work of the Ellis survey (van der Schalie and van der Schalie, 1950) and of Marian E. Havlik (personal communication) has furnished much background material about Pool 10 naiades.

Hay Point Bank Repair (Exhibits 26 and 80)

Because it is of the construction variety, this Site was not being maintained in 1977, but dredging was to occur as part of the bank repair, so a definitive investigation was made.

The Hay Point Site supports an excellent mussel community, whose focal point is two commercial beds (Exhibit 47), long known to local folk (personal communications). Although greatly dominated by *Amblema plicata*, the fauna is species-rich.

Occasional channel maintenance dredging began here in 1937 and continued through 1972 (USACE, 1974b), but it appears to have done this fauna no harm. The far more limited bank repair dredging, also, should have done none.

Pool 11 (Exhibit 82)

A species-rich and rather populous mussel fauna was found in this Pool. Ackerman's (1976a) survey is pertinent to Pool 11, and Perry (1978) provided some recent records.

Island 189 (Exhibits 27 and 83)

The samples are greatly inferior to the mussel community discovered at the Hurricane Chute Site (below) (compare Exhibits 27 and 28). The evidence of other Sites (e.g., Hay Point Bank Repair in Pool 10, above) suggests that this difference is related to habitat poverty rather than to dredging. The main channel was devoid of mussels, but this was true at Hurricane Chute, also, where there has been very little dredging (though some recently). It is possible, of course, that deposition of dredged material has been injurious to mussels here, as at any Site.

Island 189 is the only reach in Pool 11 whose dredging history was classed as "recurrent" by the Corps (USACE, 1974a). Beginning in 1946, dredging was conducted in most years through 1973, especially at the lower end of the Site.

Hurricane Chute (Exhibits 28 and 84)

The mussel fauna is very good. The Corps has dredged here only twice and recently, in 1968 and 1973 (USACE, 1974a).

Pool 12 (Exhibit 85)

The Academy studied no Sites in this Pool. The Davis and Cawley (1975) and Perry (1978) surveys provided the only previous records.

Pool 13 (Exhibit 86)

Baker (1903) and Perry (1978) provided reliable historical and/or recent records. The current list of mussel species numbers 21, whereas Baker's party found 29 at Savannah alone, and at least 30 species have been recorded from the entire Pool. Four of these (*Cyclonaias tuberculata*, *Fusconaia ebena*, *Leptodea leptodon* and *Plethobasus cyphyus*) are extremely rare

in the Upper Mississippi River today. These were not expected from any Pool. The balance of 26 species compares favorably with an all-Pool modern list that was gained *only* by brailing.

The dredging histories of the three Sites are similar and unusual. Little or no Corps dredging was performed at any of them during the early years of the 9-Foot Channel Project, but in the early Seventies dredging increased and was rather intensive at the lower two Sites (USACE, 1974a). One is tempted to associate the faunas at those two Sites (much inferior to that at Savanna (compare Exhibits 30 and 31 to Exhibit 29)) with this fact. However, most Savanna data were derived from a single good population in deep water at the base of railroad bed riprap in Savanna Bay above the town. This high mussel abundance was encountered nowhere else in the reach studied.

Submerged vascular vegetation was characteristic of all Sites, and heavy slack-water weedbeds occurred at the upper two.

Savanna (Exhibits 29 and 87)

The main channel reach exhibited a mostly sand bottom. but in Savanna Bay there was a great admixture of mud, and most mussels came from a streambed of mud and large rocks.

Sabula (Exhibits 27 and 88)

See Pool 13 Discussion (above).

Dark Slough (Exhibits 31 and 89)

See Pool 13 Discussion (above).

<u>Pool 14</u> (Exhibit 90)

The Academy's experience in this Pool was limited to part of a single Site, which supported 12 mussel species. Perry's (1978) total of 28 species for Pool 14 is understandably much higher.

Locks and Dam 14 Upper Approach (in part) (see Pool 15, below) (Exhibits 32 and 91)

This Site was physically circumscribed, permitted few brail runs, and offered no sampling peculiarities - except

for being divided between two Pools.*

The Locks and Dam 14 Upper Approach Site exemplifies the good brailing consistently found in association with riprap (in this case, in the main channel border on the Illinois side). It is among the few 1977 Sites that exhibited plentiful mussels at points within their stipulated boundaries, but not within the probable influence of dredging. There is (or was) along the Illinois shore adjacent to the head of the Upper Approach a mussel bed of commercial proportions, which had been heavily worked by clam fishers during the summer. The Academy crew found no unequivocal trace of this bed in the area pointed out by local people. Perhaps the riprap samples represent all that is left after the summer's depredations. At any rate, the outsider apparently must make a special effort in order to locate and delineate the bed. The Principal Investigator determined that such extraordinary search would be inappropriate to the goals of the present project. There has been no attempt to map the bed for this report.

The Upper Approach was dredged rather heavily in 1953 and 1972, but otherwise very little. There is no discernible correlation between its mussel fauna and this history. That fauna is poor (Exhibit 91), but not worse than what lies below the Locks and Dam (Exhibit 93).

Pool 15 (Exhibit 92)

The Academy examined only a portion of one Site in this Pool, and few mussels were gathered. However, there is a wealth of other information about the naiad fauna of Pool 15, which has been gained from Thomas M. Freitag (personal communication, Rock Island District, Corps of Engineers), Ecology Consultants (1977), and Perry (1978).

In choosing to refer data to Pool 15, Pool 16, or both, the boundary between the two becomes a problem. Locks and Dam 15 (RM 482.9, Davenport, Iowa) is an unsatisfactory "biogeographic" boundary because it does not fully traverse the Upper Mississippi River, whose east channel (as a passage called Sylvan Slough) flows between Arsenal Island and the Illinois shore unaffected by this installation. The river

* This is true of two other Sites: Locks and Dam 1 Upper Approach Construction (Pool 2, above) and Locks and Dam 5 Culvert Construction (Pools 5 and 5A, above). However, in those cases mussels were secured from only one side of the installation, the lower and upper, respectively (but see the discussion of the Locks and Dam 5 Site for a qualification of this point).

above Sylvan Slough clearly is part of Pool 15; below, 16. To which Pool does Sylvan "belong"? The upper (15) is the better biological choice, because it is from upstream that this Slough is chiefly influenced. Thus are ascribed to Pool 15 the non-Academy data mentioned above, of which many have exclusively to do with Sylvan Slough.

These data, plus the Academy's, show a living naiad fauna of well over 20 species in Pool 15 (as opposed to a recorded total of at least 31). That most of this information concerns Sylvan Slough among the Quad Cities, a heavily urbanized area, is especially encouraging. Elsewhere in the Pool, of course, there could be other kinds of environmental disturbances that are detrimental to mussels (backwater landfill, local toxic point sources, etc.), but the overall naiad picture for this Pool is very good.

Locks and Dam 14 Upper Approach (in part) (see Pool 14, above) (Exhibits 32 and 93).

Some Corps dredging has occurred shortly below this Site, but none within the Pool 15 share of it. The mussel samples are a species-poor fraction of what is known about this Pool (compare Exhibits 92 and 93).

Pool 16 (Exhibit 94)

Only one Site was studied in this Pool, but mussel collecting was good there (Exhibit 95) and there are dependable previous data, so a reliable assessment of changes in Pool 16 is possible. With the exception of a few rare or Endangered species, the historic and present faunae are very similar in terms of number and variety of mussel species, although, as almost throughout the Upper Mississippi River, there doubtless have been changes in relative population sizes, many of which have gone undetected thus far.

Centennial Bridge (Exhibits 33 and 95)

Channel maintenance dredging has occurred intermittently at this Site, including two occasions in the early Seventies, and the resulting material, mostly sand with some rubble, has been deposited on the foot of Arsenal Island and along the Illinois bank below the Centennial Bridge (USACE, 1974a). These activities appear to have killed rare *(Tritogonia verrucosa, Plethobasus cyphyus)*, Endangered *(Lampsilis higginsi)*, and proposed Threatened *(Cumberlandia monodonta)* species of mussels. Environmentally and practically, *C. monodonta* is probably the most significant of these four. This species may have been dredged here in 1977 and will

continue to pose a problem at this Site. This difficulty will be magnified if the animal achieves the proposed legal jeopardy rank. Persons and agencies who expect to dredge or otherwise to disturb streambed here will have to exercise utmost caution.

An encouraging feature of this Site is the diversified and rather individual-rich naiad population that dwells in gravel beneath about 10 feet of water immediately below Centennial Bridge. This population has thrived through decades when dredged material was cast loose upon the shore only yards away. The implication is that decay of this "spoil bank" has done the adjacent mussel bed little or no harm.

Opposite this bank and just off the Iowa shore there is an extensive area of muddy streambed that is strewn with major trash (bicycle frames, hoop nets, etc.). Here were taken fewer mussels, and these were dominated by a single species, *Amblema plicata*. This population contrasted sharply with the previous one and may partly counter Kaskie's (1971) contention about mud's being the most suitable streambed for mussels.

Along the right bank near the foot of the Site are muddy shallows where some young mussels were taken, including juveniles, rarely encountered, of *Quadrula quadrula* and *Lasmigona complanata*.

Pool 17 (Exhibit 96)

More or less current information demonstrates 28 living mussel species for this Pool, whose fauna has fared well over the years: the historical fauna, also, totals 28 species. Recent captures of living naiads by commercial clammers include three rarities (*Fusconaia ebena*, *Tritogonia verrucosa*, and *Plethobasus cyphyus*) and the Endangered *Lampsilis higginsi*.

Bass Island (Exhibits 34 and 97)

In 1946 the Corps began occasional, moderate dredging that continued through 1974 (USACE, 1974a). Some mussels were found in the main channel, though none of these species was unexpected, whereas most were brailed in backwater sloughs and the main channel border on the Iowa side, where the substrate was almost entirely mud. Scraping in shallow areas produced a few young *Amblema plicata* only. Clearly, this is a habitat-poor Site, whose fauna does not match the better assemblages known from Pool 17 at present.

Edwards River (Exhibits 36 and 100)

The numbers of species and of individuals were superior to those at the New Boston Upper Site. By a wide margin *Amblema plicata* was the most plentiful species, but dominance was shared with *Quadrula quadrula*, *Q. pustulosa*, and *Obliquaria reflexa*. The unusually large number (10) of *Q. metanevra*, a rarity, is a positive reflection upon environmental quality here.

Excepting a very large removal of material in 1968, dredging at this Site has been moderate to light (USACE, 1974a). There was a flurry of Corps dredging in the late Forties, but then almost none for 20 years, whereafter it resumed and was perennial (though not more than moderate) in the early Seventies through 1973.

Pool 19 (Exhibit 101)

The 25 mussel species found by the Academy compare very favorably to the total of 28 that have been recorded from Pool 19. The fauna was dominated by *Amblema plicata*, but several other species were abundant. In order of descending dominance, these are *Quadrula pustulosa*, *Q. quadrula*, *Q. nodulata*, *Truncilla donaciformis*, *Obovaria olivaria*, *Anodonta imbecillis*, *Obliquaria reflexa*, *Megalonaias gigantea*, and *T. truncata*. This order seems to be essentially typical of the Upper Mississippi River (Exhibit 53) and of its basin (Exhibit 49).

Two previously recorded rarities (*Tritogonia verrucosa* and *Fusconaia ebena*) were not found. On the other hand, one species that is rare (*Quadrula metanevra*) and one that is proposed as nationally Threatened (*Cumberlandia monodonta*) were taken in Pool 19. Regardless of these records, the strength of this Pool lies in its harboring such a large proportion of the Upper Mississippi's widely distributed mussels.

Craigel Island (Exhibits 37 and 102)

The Corps began dredging this reach in 1947 and pursued the practice through 1973 (USACE, 1974a). Excepting a large removal of material in 1969, dredging has been of no more than moderate proportions. Moreover, it has been essentially infrequent and irregular and had occurred only thrice during the decade prior to 1973.

Dredging and associated activities appear to have applied little or no adverse pressure upon the mussels of the Craigel Island Site. Its 18 species compare well to

faunas at most other Sites studied in 1977. An ordinary combination of dominants in lower Upper Mississippi River Pools was apparent: the foremost species by far was *Amblema plicata*, but *Quadrula pustulosa* (especially), *Q. quadrula*, *Fusconaia undata*, and *Obliquaria reflexa* shared domination thereafter.

This Site contains a clearly defined point source. Near the foot of the Site on the Iowa shore opens a discharge canal from the Burlington Generating Station of the Illinois Southern Utilities (ISU) Company. Below the ISU outfall there were few mussels, most of which bore traces of what presumably was iron floc. Mussels became more common farther downstream in the vicinity of the daymark at RM 398.2.

While investigating the ISU outfall effects, the Academy crew passed the lower terminus of the Craigel Island Site and almost at once came upon a rich mussel bed beginning in the main channel border close to the black buoy line and extending into the navigation channel. The bed was dragged by brail for about 2,000 ft below the Site. Most of it lay beneath the greater part of 20 ft of water. Several points are indicated by this discovery.

First, imputation to the Corps of responsibility for mussel poverty can be mistaken. Consideration must be given to nearby point and non-point sources of environmental disturbance.

Second, mussel beds are not necessarily restricted to shallow waters close to shore. Where suitable substrate lies undisturbed beneath a permanent sufficiency of water, a bed can develop. Clearly, the long-term stability of the habitat is the most important factor so long as the streambed is appropriate to the species or community.

Third, failure to find the bed extending across the main channel border closer to shore probably reflects human intervention, perhaps by commercial SCUBA divers.*

Fourth, mussel beds can exist close to dredged areas - and even immediately downstream from them in the main channel - if whatever pertubation caused by dredging and associated activities is not followed by regular disturbance from

* A similar situation was encountered at Dallas Island (below), a "Green Bay" Site in Pool 19.

other sources (e.g., large craft) and if the water is deep enough to obviate such disturbance.

Some of these considerations are especially relevant to findings among the "Green Bay" Sites (below).

The "Green Bay" Sites (Exhibits 38 and 103)

Turkey Island
Thompson Island
Dallas Island
Pontoosuc
Hog Island

The relevant Upper Mississippi River reach occupies RM 386.5 to RM 395.0. Mussel community composition of this reach in 1977 was essentially the same as that described for Pool 19 in general (above). The remarkable thing remains the discovery of *Cumberlandia monodonta* at two Sites.

The dredging history anywhere in the "Green Bay" reach is miniscule (USACE, 1974a). These Sites were studied because of proposed dredging of material for use in levee raising.

Turkey Island (Exhibits 39 and 104)

Completely dominated by *Amblema plicata*, the mussel fauna was otherwise somewhat similar to that for Pool 19 (compare Exhibits 101 and 104).

This Site exhibited an unusual feature, the opportunity to sample young adult mussels, in sandy shallows between the Iowa bank and the islands just offshore. Some submerged vascular vegetation was present, but none of it seemed to harbor juvenile mussels. This area (at about RM 394.3) supported another kind of juvenile, however: *Corbicula fluminea*, the Asiatic Clam (see St. Croix River, Hudson Site, above). This exotic's arenophilia means that the animal probably will bloom at this Site now that, unfortunately, it has arrived.

Thompson Island (Exhibits 40, 48, and 105)

The 20 species at this Site (much like the list for Pool 19) were dominated by adults of *Quadrula nodulata*, in particular, followed (in order of descending abundance) by *Q. pustulosa* and *Megalonaias gigantea* and then by *Q. quadrula* and *Truncilla donaciformis*.

Much of this Site is sandy streambed, which produced few mussels, and most material was brailed from presumably old beds near wing dams.

There is a commercially harvested mussel bed in Dallas Chute just offshore from Dallas City. The Academy brailed into the head of this bed near the foot of the Thompson Island

Site and then continued sampling downstream until the bed thinned out shortly below Dallas City. These samples are ascribed to this Site even though they were secured from a reach that, by definition in terms of river mileage, actually is part of the Dallas Island Site (see the West Newton Site, Pool 5, for a rationale in the case of this survey's only similar situation).

The Dallas City bed has been mapped (Exhibit 48). It is best developed between the upper and lower limits of shoreline settlement. The bed was wholly dominated by the same species that dominate the Pool 19 fauna (discussed above), with the exceptions of *Obovaria olivaria* and *Anodonta imbecillis*. The dominants, plus some of the less common species, exhibited a wide range of size classes, including small mussels and juveniles. This indicates ongoing recruitment to the bed.

Dallas Island (Exhibits 41, 48, and 106)

The 22 species from this Site were somewhat more numberous, plentiful, and diversified than those at the Thompson Island Site (just above), but they exhibited much stronger and more narrow dominance, by *Quadrula quadrula*, *Q. nodulata*, (especially) *Q. pustulosa*, and *Obovaria olivaria*. This pattern is something of an artifice, however, inasmuch as many of these quadrulae and *Obovaria* are young individuals that had colonized an extensive area of mud and sand in shallows along the Iowa shore (opposite Pontoosuc, Illinois) from which industrial interests removed great quantities of dredged material a decade or so ago.

The ability of these animals to recruit themselves reflects most favorably upon environmental quality here and among the "Green Bay" Sites generally. The same point is true of this Site's mussel bed, also.

This bed is mapped in Exhibit 48. It lies in the main channel off and below Farmers Dock on the Iowa side. It *used* to lie in the adjacent main channel border, as well, but weeks of work by commercial SCUBA divers prior to the Academy's visit (Richard J. Jones, personal communication, Rock Island District, Corps of Engineers) evidently had decimated that portion of the bed, for almost no mussels could be brailed offshore within the black buoy line. (It appears that the divers wisely dared not venture into the channel; hopefully, that prudence will preserve the rest of the bed in the future.) Similarly, a local fisherman (personal communication) drew attention to another bed, above Farmers Dock at about RM 391 in the Island 385 vicinity, but extensive brailing failed to discover it. Perhaps that bed, too, has been spoiled by professional clammers.

The remainder of the Dallas Island Site bed is otherwise of some interest. It includes at least 20 mussel species, which are dominated by quadrulae, nobably *Quadrula pustulosa*. More important, though, is the presence of *Cumberlandia monodonta*, the Spectacle Case, proposed as nationally Threatened. Several specimens were secured from this bed (Exhibit 48), probably in association with wing dams (see discussion of *C. monodonta*, below).

The location of the Dallas Island bed in portions of the navigation channel deserves further commentary. Depending upon river stage, water depth here can be in the 20- to 30-ft range. These depths not only obviate channel maintenance dredging (see the Craigel Island Site, above), but also protect the benthos from mechanical damage caused by large and small craft. It is of the greatest significance to realize that adequate water depth, not just riverbed type, is a determining factor in mussel survival in the main channel of the Upper Mississippi River.

Pontoosuc (Exhibits 42, 48, and 107)

This Site exhibited "seams" of mussels, but no beds. Its fauna is species-rich, but individual-poor in comparison to those of other "Green Bay" Sites. The fauna was clearly dominated by *Quadrula quadrula*. As in much of the rest of the "Green Bay" reach, most mussels were gained from mud bottoms in about 20 feet of water. Except for the number and variety of its species, this fauna was an ordinary one, yet *Cumberlandia monodonta* was found here (Exhibit 48), as well as at the Dallas Island Site (above).

Hog Island (Exhibits 43 and 108)

The fauna of this Site was ordinary in that it was overwhelmingly dominated by *Amblema plicata*, but extraordinary on account of its species-richness and the many individuals of most taxa that were present.

The most notable habitat at the Site is an extensive weed-choked shallow-water area over muddy sand at the head of Hog Island. Here were found enormous numbers of *Amblema plicata* of all ages (mostly unrecorded in Exhibit 108), plus many *Obliquaria reflexa*, *Anodonta imbecillis*, and *Proptera laevissima*. This area, even more than a similar one at the Turkey Island Site (above), is a classic example of the value of backwaters as nursery grounds for mussels (and their piscene glochidialhosts). Read and Oliver (1953) held that young mussels will migrate from a nursery ground to colonize new areas or to recolonize old ones. It is unlikely, on the other hand, that the beds in the Dallas Island reach depend

upon the faraway Hog Island backwater for direct repopulation, but the backwater refugial populations doubtless indirectly benefit the deep-water, riverine beds by forming a reservoir of larvae, some of which make their way to the beds as parasites on fish. The need to protect slack- and shallow-water areas from the Corps' dredged material (acting, in effect, as landfill) - and from any other adversities - is obvious.

A single valve of an Asiatic Clam, *Corbicula fluminea*, was found in this backwater (see the Hudson and Turkey Island Sites, above).

POOL 20 (Exhibit 109)

The Site records (Exhibits 110 and 111) are species- and individual-poor. The samples from both Sites are weakly dominated by *Quadrula quadrula*, *Q. pustulosa*, and *Amblema plicata*. This evidence compares very poorly with the recorded total of 24 species in Pool 20.

Both Sites exhibited massive and extensive dredged material placement areas. The dredging histories of the two are quantitatively very different (see below). One implication is that the "spoil banks" are very unstable and have spread. If spreading into the river has occurred (as appeared to be so), it is probable that mussels have been killed by inundation with dredged material. Another implication is that such mortality cannot be the sole factor depressing these two faunas; the presumably Corps-induced pressure (i.e., dredging) is quantitatively unlike at each Site, yet their faunas are essentially identical.

Another, apparently far more serious factor is the Des Moines River, which may be the most adverse influence upon Pool 20, at least in the latter's upper portion. Entering just below Keokuk, Iowa, along the Iowa-Missouri state line, the Des Moines acts as a damaging point source upon the Mississippi at their confluence. The Des Moines was observed to convey suspended matter and surface foam. Discharge occurs little more than one mile above the head of the Fox Island Site. Local fishermen (personal communications) believe that the Des Moines contributes large quantities of sand to the Mississippi, doubtless including some of the material of which the Corps endeavors to rid the navigation channel. The impacts of urban pollutants, agricultural runoff, and bedload have unarguable effect upon Pool 20. How far this impact may extend is moot, but it is worth noting that the mussel fauna at Howards, the only Site investigated in Pool 21, about 15 River Miles below, is hardly superior to those sampled in Pool 20.

Compounding these unfortunate circumstances is realization that the Des Moines River once was not an environmentally troublesome stream, but a haven for benthic life. For example, Shimek's (1888) paper implies that a century ago the Des Moines must have supported a magnificent mussel fauna; he emphasized the occurrence there of two rarities, *Alasmidonta marginata* and *Simpsoniconcha ambigua*. The Academy has not further researched the Des Moines. A comprehensive environmental study of that river is needed and imperative for its own sake and the sake of its influence on the Mississippi.

Fox Island (Exhibits 44 and 110)

The presumable adverse influence of the Des Moines River was expecially evident here in terms of there being uncommonly poor mussel brailing in about 10-foot waters off riprap.

There was no Corps dredging at this Site until 1957 (USACE, 1974a). Thereafter it was almost perennial and usually heavy through 1973.

Buzzard Island (Exhibits 45 and 111)

Corps dredging did not begin here until 1959 (USACE, 1974a). Subsequently it was intermittent and (with the exception of a large volume in 1963) rather light.

POOL 21 (Exhibit 112)

Here the Academy examined a single Site, which furnished 11 naiad species, apparently the only current records for Pool 21. Historical records total 20 species. As suggested earlier (see Pool 20, above), the factor responsible for this difference may well be the Des Moines River, whose damaging influence upon the Mississippi is probably about as old as the urbanization of Des Moines itself and the agricultural growth of the surrounding countryside. These phenomena are of almost a century's antiquity (WPA, 1938).

Howards (Exhibits 46 and 113)

The Howards Site offers two interesting peculiarities. First, it is an example of the importance to mussels of stable streambed at the base of riprapped banks. Second, an extraordinary number of dead shells was found on dredged material. Their origin(s) is/are unclear: the Rock Island District Environmental Impact Statement (USACE, 1974a) mentions no disposal areas in the reach that includes this Site. Nevertheless, the shells doubtless came from within Pool 21. The Academy's observations on the composition of these bones and gapers were restricted to noting that they included species in excess of the living taxa noted in Exhibit 113. This point and Perry's (1978) work suggest that the impoverished fauna that is recorded for this Pool is somewhat a result of inadequate search, as well as the suggested, strongly negative impact of the Des Moines River.

Corps dredging at the Howards Site has an unusual history. Dredging has varied from moderate to heavy, but, commencing in 1947, it persisted only through 1968 (USACE, 1974a).

POOL 22 (Exhibit 114)

The Academy studied no Sites in this Pool. The historical record shows 22 mussel species.

POOL 23

There is no Pool 23 because there are no Locks and Dam 23.

POOL 24 (Exhibit 115)

The Academy studied no Sites in this Pool, for which there are historical records of up to 27 mussel species.

The van der Schalies (1950) presented the Ellis survey's mussel data in a synoptic fashion according to "Zones" of the Upper Mississippi River; their "Zone XII" includes both the modern Pools 24 and 25. Accordingly, all "Zone XII" Ellis data are given (and queried) in both Exhibits 115 and (for Pool 25) 116. The records for either or both Pools include two animals that are very rare in the Upper Mississippi River (*Fusconaia ebena*) or nationally Endangered (*Proptera capax*), as well.

POOL 25 (Exhibit 116)

Up to 22 mussel species have been recorded for this Pool. See the discussion of Pool 24 (above).

POOL 26 (Exhibit 117)

The Academy studied no Sites in Pool 26. There are some historical mussel records, which number 21 species. One of these is extremely rare in the Upper Mississippi River (*Tritogonia verrucosa*); another, nationally Endangered (*Proptera capax*).

POOL 27 (Exhibit 118)

The Academy has no information concerning the mussels of this Pool.

BELOW POOL 27 (Exhibit 119)

Eighteen mussel species have been recorded from this free-flowing reach between Locks and Dam 27 and confluence with the Ohio River. This total includes the Upper Mississippi's only record for *Proptera purpurata*.

Species-Group Mussel Taxa

This section of the report presents introductory natural histories of the historically and/or currently known Upper Mississippi River fresh-water mussels. The remarks deal principally with genus- and species-group taxa. Topics of discussion include habitat, geographic range (nationally and in the Upper Mississippi River), jeopardy status (in ecological and/or legal contexts), reproductive success, symbiotic relationships, and miscellaneous remarks, as needed. Most information about larval hosts appears in Appendix D.

Larval host data concern the most important aspect of mussel life: the period of parasitism that usually must be passed on a vertebrate host by the larva (glochidium) after its release from the female parent. Ordinarily, the host is a fish, and the parasitism is obligate. Occasionally, parasitism is facultative, and the host is an animal other than a fish. There are four such exceptions known in the Nearctic region; each occurs in the Upper Mississippi River naiad fauna and is treated among the accounts that follow.

Disruption of the ichthyofauna can and often does involve negative impact upon the mussel community. Some classic examples are given below. In terms of principles and empirical data, the whole matter was more fully discussed by Fuller (1974b).

More is known about the larval hosts of Upper Mississippi River mussels than about those of any others in the world (chiefly because of research conducted by staff of the United States Bureau of Fisheries Mussel Propagation Laboratory at Fairport, Muscatine County, Iowa, during the first quarter of this century). In some cases, it is possible to correlate a mussel species' decline with damage to its host fauna.

There are, however, important gaps in our knowledge of glochidial parasitism, as will become apparent below. This means that immediate, informed steps toward conserving the mussel resource often cannot be taken.

Discussions of the following topics occur under the indicated headings.

Cumberlandia monodonta--wingdams and other rocky substrates

Quadrula pustulosa--local dominance of mussel community by *Quadrula*

Tritogonia verrucosa--causes of mussel decline; need for physiological research into Nearctic mussels

Cyclonaias tuberculata--need for popular training in mussel identification; mussel species that are below recruitment level and/or rare in the Upper Mississippi River

Proptera alata--mussels as multiple symbionts

Truncilla donaciformis--adults as the most vulnerable stage in the mussel life cycle

Lasmigona complanata--the habitat characteristic of the Anodontinae

Cumberlandia monodonta, Spectacle Case

This elusive species has been taken from muddy, vegetated streambeds (Stansbery, 1966), but it ordinarily favors rocky areas, often beneath deep and rushing waters. It is often found within recesses among boulders or in spaces beneath rocks that are loosely in contact with the riverbed. The Academy's 1977 samples of living Spectacle Case may well have been taken from wingdams.

Rocky habitats have never been commonplace in the Upper Mississippi River, but they are now extremely rare because of dredging and blasting carried out to facilitate commercial navigation. Therefore, the proposed nationally Threatened status of *Cumberlandia monodonta* is certainly appropriate to the Upper Mississippi.

This proposed status suggests that the Corps, chief destroyer of rocky areas in the Upper Mississippi, must locate and thereafter avoid populations of Spectacle Case. This point applies equally to other governmental agencies and to the private sector and is especially germane to the Rock Island District, where *Cumberlandia monodonta* and rocky habitats (including wingdams) are especially prevalent.

There is a long-standing opinion that wingdams-especially the emergent ones-are ecologically harmful (see, e.g., Fuller, 1974b). In the present era of the 9-Foot Channel Project, however, most wingdams are submerged and are increasingly interpreted as an environmental asset (e.g., as a habitat for certain fishes). The probability that the Spectacle Case inhabits wingdams augments the supposed value of that asset and imposes a legal premium on not dismantling those erstwhile obstructions to free flow of the Mississippi.

It is ironic that, although wingdams apparently are refuges for fishes and Spectacle Case alike, no glochidial host for *Cumberlandia monodonta* is known. The widespread belief that Margaritiferinae are parastic upon Salmonidae (trout and salmon) is mistaken because *Margaritifera hembeli* (Conrad) of the Gulf drainage dwells where there are no indigenous salmonids. If the Spectacle Case does require a larval host, the host's identity obviously is not necessarily to be inferred according to traditional criteria - Utterback's (1928) statement that *C. monodonta* is capable of two broods per year suggests that this species' reproduction is atypical of Nearctic mussels'. Rational candidates for glochidial host(s) of the Spectacle Case are, for example,

one or more developmental stages of a vertebrate amphibian (see Seshaiya, 1941). The problem is complicated by this mussel's extensive geographic range, in which more than one glochidial host is possible.

Cumberlandia monodonta is restricted to the Mississippi River basin, where once it was widespread, though now its distribution is patchy. Spotty distribution of the Spectacle Case is typical of the Upper Mississippi River, also. *C. monodonta* has been recorded from several Upper Mississippi Pools, expecially in the Corps' Rock Island District, and some of those records are based on recently collected living animals.

Quadrula metanevra, Monkeyface

This species is (or was) widely distributed in the larger streams of the Mississippi basin, but apparently it has always been among the less common mussels in most places where it occurs. Certainly it is a rarity in the Upper Mississippi River, but it can be found in many Pools and shows evidence of recruitment, however marginal. Only a few species of glochidial hosts (sunfishes and the Sauger) are known, but these include fishes of wide and plentiful occurrence in the Upper Mississippi (Smith et al., 1971). Perhaps it is the small number of hosts that is responsible for the Monkeyface's poor reproduction (but see *Quadrula quadrula*, below). However, a more likely cause is decline of favored habitat after Upper Mississippi impoundment. *Q. metanevra* is highly characteristic of dense mussel populations on gravel bars or in stable mud areas. This species may be endangered; its relative abundance has declined since the time of the Ellis survey, when it came to 2.61% of the fauna, largely because of the now astonishing 143 specimens from Pool 18 (see van der Schalie and van der Schalie, 1950).

Quadrula quadrula, Mapleleaf

This species was once so uncommon in the Upper Mississippi River that mussel fisherman, aware of its commercial value, called it the Stranger (Coker, 1919). However, *Quadrula quadrula* is tolerant of impoundment conditions and, as one of the initial successful colonizers, often exploits them (Bates, 1962). This is the more remarkable in that the Mapleleaf has only one recorded glochidial host, *Pylodictis olivaris*, Flathead Catfish, "fairly common throughout the river" (Smith et al., 1971). This mussel's representation in the Upper Mississippi River had risen to 4.06% by the time of the Ellis survey (the van der Schalies, 1950) and was 5.92% of the fauna in the

1977 study area. The latter figure would be much higher if calculated solely from data for the lower Pools, where *Q. quadrula* is far more common than it is farther north. The species is widely distributed in the Mississippi basin and the western Gulf drainage. In the Upper Mississippi it can be expected on almost any type of streambed with the exception of finely divided, unstable materials; however, it is sometimes found on shifting sand in the main channel.

Quadrula nodulata, Wartyback

Like *Quadrula quadrula* (above), *Q. nodulata* has experienced an increase in its proportion of the Upper Mississippi River naiad fauna, but in this case a sharp one, from 1.51% of Ellis' records (see the van der Schalies, 1950) to 3.80% of the Academy's current ones. Again like the Mapleleaf, the Wartyback tolerates broad habitat variety, including impoundment. Reproduction is excellent: in most Pools a large proportion of individuals was very young. As noted by Yokley (1973), for example, young and old alike can flourish in rather fine sediment, so the slow death by sedimentation of Upper Mississippi river-lakes apparently poses little threat to *Q. nodulata*. Also in its favor is that many of its known glochidial hosts are fishes that remain common and widespread among the Pools (Appendix D; Smith et al., 1971). Still widespread in the Mississippi basin, this increasingly populous species holds promise of perpetuating the important ecosystematic role of mussels in general.

Quadrula pustulosa, Pimpleback

This is yet another *Quadrula* that has increased its proportional representation in the Upper Mississippi River mussel fauna during recent decades: it was 4.98% (itself a generous share) of Ellis' samples in 1930 and 1931, but rose to 8.86% of the Academy's collection in 1977. The habitat and geographic range of the Pimpleback are very like those of *Q. quadrula* (above), but it is even more tolerant of certain substrates (sand, silt) that are unfavorable to most mussels. Also, *Q. pustulosa* has much the greater number and variety of glochidial hosts (sturgeon, catfishes, crappie). Thus it is not surprising that the Pimpleback ranked second (*Truncilla donaciformis* intervened) to the most plentiful species (*Amblema plicata*) on the Academy's 1977 list (*Q. quadrula* was next, in fourth place, and *Q. nodulata* ranked seventh).

Tritogonia verrucosa, Buckhorn

Formerly widespread and rather common in the Upper Mississippi basin, *Tritogonia verrucosa* was encountered alive only once during this survey, at the Hudson Site (Exhibit 52). It tolerates many types of streambeds, though gravel is surely optimal. In any case, physically suitable habitats occur in most Pools, so the Buckhorn's decline has been caused by other factors.

Unfortunately, no glochidial host appears to be known. Smith et al. (1971) noted numerous Upper Mississippi River fishes whose historical ranges have been gravely reduced; these may include the host(s) of *T. verrucosa*. On the other hand, this mussel ranges widely in the Mississippi basin and the Gulf drainage; in so great an area it probably employs a redundance of hosts. If this is true of the Upper Mississippi River, host fish unavailability is *probably* a minor problem for the Buckhorn.

Nevertheless, this species appears nearly extirpated in the Upper Mississippi, and no conceivable factor in its decline can be ruled out. Perhaps the instrumental one simply is the direct impact upon the mussel, rather than the fish, of unfavorable water quality. That *Tritogonia verrucosa* persists in the St. Croix River, a cleaner stream, suggests as much, even though any relevant chemical details remain obscure. Such obscurity surrounds all mussel species that have declined in the Upper Mississippi River, but the assumption that toxic substances and pathogenic microorganisms are at least locally at fault is indicated by the extirpation of most or all species for miles below the Twin Cities. (This point is emphasized by the unexpected discovery of excellent mussel populations in the Quad Cities area in 1977. Moreover, almost 50 years ago Ellis (1931b) demonstrated that Upper Mississippi mussels' reproduction was being disrupted by bacteria and protozoans.) Perhaps the Buckhorn is an example of a mussel that is exceptionally sensitive to poisoning and disease. This would account for its widespread disappearance.

In any case, the development of knowledge about disease and physiological disruption of Nearctic mussels is in its infancy. European workers - notably the Hungarian school epitomized by Lucacsovics and Salánki-have made great experimental advances in regard to their fauna, but their discoveries cannot reliably be imputed to other mussels except in the sense of broad (and possibly misleading) generalizations. This difficulty is aggravated in the case of species-group taxa of a different biogeographic province.

A report like this requires taxon-specific information. With a few exceptions (e.g., Chin, 1972; Badman and Chin, 1973; Dietz, 1974), the North American "school" has accomplished nothing.

Because of the Buckhorn's increasing rarity in the Upper Mississippi River, it poses a decreasing practical problem for agents, including the Corps, who manipulate the river and its bed. On the other hand, problems can have ethical, ecological, and legal dimensions. In this context, efforts to conserve *Tritogonia tuberculata* would be more honest, wise, and safe, respectively. Because of his knowledge of healthy populations elsewhere in the Buckhorn's range, the Principal Investigator cannot logically propose that this species be accorded a national jeopardy rank, but at least some states' considering it Threatened or Endangered would be consonant with its status in nature.

The one paper ever devoted exclusively to this species (D. Jones, 1926) scarcely illuminates any of the issues considered above and clarifies none.

Cyclonaias tuberculata, Purple Pimpleback

Uncommon even at the height of the pearl button industry, *Cyclonaias tuberculata* is now probably extinct in the Upper Mississippi River. There apparently have been no living records for many years, and almost 50 years ago the Ellis survey discovered only two specimens alive. The nominal subspecies *C. t. strigillata* of the Upper Tennessee River drainage is being considered for federal protection, and other populations of *C. tuberculata* should be identically considered.

Purple Wartyback prefer silt-free areas (Yokley, 1973) in gravel and rock riffles and are sometimes found lying free in bedrock areas. Such habitats are essentially long since gone from the Upper Mississippi River. Compounding this species' problems is complete ignorance of its glochidial host(s). It is very probable that, with the possible exception of the Endangered *Proptera capax*, there is no Upper Mississippi mussel now less likely to be encountered than this one. Still widespread in the Mississippi basin, the Purple Wartyback grows less and less common in most of its range.

Cyclonaias tuberculata illustrates two noteworthy items. Even if it were legally protected in the Upper Mississippi River, unfamiliar investigators (i.e., most of them) would

be hard pressed to distinguish this species from the (White) Wartyback, *Quadrula pustulosa.* Well preserved shells offer no problem, but excellent conchological material of the *Purple* Wartyback is very rare. Mantle margin features provide unequivocal discriminants and are easily observed in living animals, but they are foreign to most students, including many avowed naiadologists. Education of specialist and non-specialist alike to these subtleties is imperative.

Second, the Purple Wartyback is an example of an animal, natively uncommon in an area, whose population draws down below recruitment level in response to environmental hardship. In other words, individuals become so few that they cannot provide enough offspring to equal or surpass the species' mortality. The Principal Investigator suspects that this has happened or is happening to a number of Upper Mississippi River mussels. This interpretation is best applied only to animals that are known once to have been viable (though perhaps rare) elements of the fauna. Upper Mississippi River mussel species that are likely candidates in much, perhaps *all*, of their ranges in the study area are *Tritogonia verrucosa, Plethobasus cyphyus, Pleurobema cordatum, Elliptio crassidens, Proptera capax, Leptodea leptodon, Lampsilis teres, L. higginsi,* and *L. radiata siliquoidea.*

Species that historically have always been rare in the Upper Mississippi, but are essentially small-stream strays, include *Actinonaias ellipsiformis, Lasmigona compressa,* perhaps *Alasmidonta marginata,* and *Anodontoides ferussacianus.* These are not to be equated with the previous category, although it is true that descent below recruitment level can jeopardize any species.

A third group of rarities includes mussels that have known or presumed fish host problems: *Fusconaia ebena, Ligumia subrostrata,* and *Lasmigona costata. Strophitus undulatus* probably belongs here, but either its host problem is subterminal or its facultative larval parasitism permits long-term local populations (e.g., at Prairie du Chien).

Fusconaia flava, Pigtoe

The Pigtoe appears not to exploit impoundment so vigorously as do the quadrulae: backwater populations of young mussels contain fewer *Fusconaia flava* than *Quadrula,* and the proportion of Pigtoe has fallen off from 5.01% of the fauna in Ellis' day (see the van der Schalies, 1950) to 3.96% in the 1977 study area. However, there seems to be no great cause for concern about this animal, whose "weakness" seems to be merely a greater fastidiousness about streambed type.

F. flava has several known glochidial hosts (Exhibit 121), which include fishes of abundance and widespread distribution in the Upper Mississippi River (Smith et al., 1971). The Upper Mississippi form (*undata*) of *F. flava* is part of a taxonomically forbidding complex of animals that still enjoys its former great success in much of the Upper Mississippi basin and in the western Gulf drainage.

Fusconaia ebena, Ebony Shell

Once the backbone of the pearl button industry and the chief constituent of many (perhaps most) of the larger Upper Mississippi River mussel beds (Coker, 1919), the Ebony Shell is now almost extinct in those reaches. Recent records of living specimens are rare. Certainly the mussel fishery took a great toll, but this factor alone cannot account for the ongoing decline that has taken place. The usual explanation is that construction of the power dam at Keokuk in 1913 so disrupted migration of *Alosa chrysochloris*, Skipjack Herring, the dominant Ebony Shell glochidial host in nature, that this mussel's recruitment in upstream reaches was thenceforward doomed. Where the Skipjack still runs freely, there can be good set of juvenile Ebony Shell (as in portions of the impounded Tennessee River (J. LaTendresse, personal communication, Tennessee Shell Company, Camden, Tennessee)), but this fish-mussel relationship may not tell the whole story of the latter's failure in the Upper Mississippi.

There are other potential host fishes for *Fusconaia ebena* (Exhibit 121). These are all Centrarchidae, each of which is widespread and more or less common in the Upper Mississippi (Smith et al., 1971). Why have these not sufficed to perpetuate Ebony Shell above Pool 20? Why has *F. ebena* failed below Pool 19, where the Skipjack's migration is not arrested? (The fish has, in fact, occasionally penetrated as far up as Pool 13 during the last 20 years or so (*ibid.*).) The implication is that another, farther-reaching, more subtle agent is at work. Adverse water quality is the likeliest candidate. Sources identified and/or implicated during this study are the Twin Cities and the Minnesota and Des Moines Rivers.

Excepting a dubious record for the Pearl River in Mississippi in Grantham (1969), the range of *Fusconaia ebena* is the Mississippi basin, especially its eastern portion, and the Mobile basin of Alabama. Only from the Upper Mississippi River does this species appear extirpated, and there are streams where it thrives, seemingly unabated. For example, in Williams' (1969) brail samples from the Green, Ohio, and Tennessee Rivers the Ebony Shell exhibited natural population

structures, and in the latter two rivers it was common to abundant, even locally dominant. (Regardless of the reservations expressed above, these findings lend weight, however circumstantial, to the traditional correlation between *F. ebena* and the Skipjack Herring.) In view of this species' progress elsewhere in the basin, to propose it for protection in the Upper Mississippi River is absurd, certainly without free passage of *Alosa* into the upper Pools. It seems that the Ebony Shell was essentially an animal of the great beds. There remain enough of these to furnish it a "starter" habitat were the Skipjack to return.

Megalonaias gigantea, Washboard

Like the Ebony Shell (above), the Washboard is largely restricted to extensive mussel beds; the Academy found no solitary aged adults, though an occasional isolated young adult was found. *Megalonaias gigantea* has fared well over the years; it made up 1.17% of the Ellis survey samples and 2.49% of the Academy's. The Washboard was a valuable item in pearl button manufacture (Coker, 1919) and is now an important shell in Japanese pearl culture. Its success has much to do with the lengthy, diversified, and redundant list of glochidial hosts (Exhibit 121). The many hosts have contributed to this species' great range, which includes the Mississippi and Mobile basins and some smaller ones between in Mississippi (Grantham, 1969). The Washboard is, in turn, host to minute and poorly understood unionicolid water mites of the difficult "Sanskrit complex" (Mitchell and Wilson, 1965; Dobson, 1966; Vidrine, 1974).

The genus *Megalonaias* persists far westward from the Mississippi basin into the Gulf drainage of Mexico. Typical *M. gigantea* ranges through Louisiana and beyond, at least into the Nueces basin of western Texas (D.W. Taylor, MS). In Mexico it is replaced by an at least nominal species and congener, *M. eightsi* (Lea). East of the Mobile basin--in the Appalachicolan region of naiad biogeography (van der Schalie and van der Schalie, 1950)--*M. gigantea* is again replaced, by (the nominal) *M. boykiniana* (Lea).

Heard (1975a) found that *Megalonaias boykiniana*, which he did *not* distinguish from *M. gigantea*, is among those Appalachicolan taxa "whose range or abundance has been reduced (i.e., are now very rare or extinct in part of their present or past range, respectively)". However, no legal sanction currently affects *Megalonaias* anywhere in its range. Regardless of taxonomic controversy and potential legal considerations elsewhere *and* in view of the Washboard's good health in the Upper Mississippi and other streams (see e.g.,

Yokley, 1973), federal protection of this species does not seem appropriate.

That the Washboard is characteristic of actual beds was mentioned above. It is noteworthy that in sluggish, muddy bayous of southern Louisiana *Megalonaias gigantea* is common in the deeper waters, usually in midstream in a bed of mixed mud and gravel away from the viscous (and thus quite stable) muds close to shore. Here again is the theme of streambed stability, illustrated in a way that is uncharacteristic of the Upper Mississippi River. The traditional notion that silt-free gravel is ever the optimal substrate for mussels is crumbling into mythology as a result of the experimental results of workers like Kaskie (1971) and observations by numerous field investigators.

Amblema plicata, Threeridge

A long and varied list of glochidial hosts (Exhibit 121), tolerance of inferior water quality, and indifference to substrate type account for the Threeridge's historical success and present dominance over the Upper Mississippi River mussel fauna (from 6.91% of Ellis' material half a century ago to 35.58% of the Academy's in 1977). Of course, increasing proportional representation has occurred partly because more sensitive species have declined, and *Amblema plicata* probably is not absolutely so abundant as at the turn of the century, because of the depredations of the mussel industry. Its range, morphological variation, and attendant taxonomic problems are all reminiscent of those of *Megalonaias gigantea* (above). The Threeridge occurs, also, in certain Great Lakes and their drainages in the upper St. Lawrence River basin of the Atlantic drainage and has reached the Interior Basin of Canada (Clarke, 1973).

Uniomerus tetralasmus, Pondhorn

This species is admitted to the present document only because of the high probability that it occurs, hitherto undetected, in Upper Mississippi River backwaters, flood plain ponds, and confluent sloughs. It was not found during this survey and there seem to be no historical records of its occurrence in the study area. However, the Pondhorn lives in the vicinity of the Upper Mississippi River (e.g., Murray and Leonard, 1962).

Despite the taxonomic controversy that surrounds this animal (Appendix A), the name *Uniomerus tetralasmus* will serve.

It (and/or congeners) ranges widely in the Atlantic and Gulf drainages and in the Mississippi basin. The habitats are equally diversified, but the species is remarkable for its tolerance of ephemeral waters. Uprooted, exposed to drought and the sun, *U. tetralasmus* tolerates (and perhaps exploits) habitats that threaten dessication. Stock tanks miles from flowing water and woodland pools are characteristic habitats.

No glochidial hosts are known for *Uniomerus tetralasmus* and/or its nominal congeners. Presumably, the dominant host(s), also, tolerate(s) ephemeral waters to some extent.

Plethobasus cyphyus, Bullhead

The Bullhead faces extinction in the Upper Mississippi River despite the abundance and wide distribution of its one known host (the Sauger). Recent and current records are exceedingly rare, and the population has doubtless sunk below recruitment level. The Academy, for example, found no living material, no gapers, and few bones. Clearly, this species has been in jeopardy for years. It comprised only 0.12% of the Ellis collections, for instance, whereas reports some 40 years previously (Grant, 1886; Holzinger, 1888; Shimek, 1888) had listed *Plethobasus cyphyus* as common and more. Indeed, Shimek considered it "very abundant on sandy bottoms" (an unlikely habitat) in the Iowa River. Yokley (1973) noted that this species and *P. cooperianus* (Lea) are now very rare in the impounded Tennessee River. His only specimens were secured from silt-free gravels. One of his *P. cooperianus* was gravid. Fertilization can occur even among so few animals, but, lacking suitable habitat(s) and/or glochidial hosts, the larvae do not adequately metamorphose, mature, and replenish the stock. The several *Plethobasus* are probably better candidates for legally Endangered status than some of the mussels already on the list. Stansbery (1976) considered two endangered and a third (the Bullhead itself) as of special concern in Alabama.

Pleurobema cordatum, Ohio River Pigtoe

The Ellis survey found 10 specimens, all in Pool 4. The Academy's material is less plentiful and more widespread. Obviously, *Pleurobema cordatum* was rare 50 years ago, and Coker (1919) had said as much a decade earlier. Early papers (Grant, 1886; Holzinger, 1888) do not dwell on this species, though Shimek (1888) thought it common in the Iowa River. Whether or not this species will ultimately disappear from the Upper Mississippi, the animal does better elsewhere, as in the impounded Tennessee River (Yokley, 1973) and especially in the Ohio and Green Rivers (Williams, 1969).

The one known Upper Mississippi River glochidial host, the Bluegill (Exhibit 121), remains "abundant throughout the river" (Smith et al., 1971), but the point is chiefly academic, for the record strongly suggests that for reasons unknown *Pleurobema cordatum* has never been successful in the Upper Mississippi. During one of the few studies of a mussel species' general biology, Yokley (1972) discovered another, more suitable fish host, which has never been recorded from the Upper Mississippi (Exhibit 121; Smith et al., 1971). Perhaps Bluegill are not competent larval hosts for *P. cordatum.*

The Academy's few specimens were secured, perhaps not on true beds, but certainly from prime habitat in the company of many mussels.

The relationships of *Pleurobema cordatum* to its congeners are uncertain; *Pleurobema* remains the taxonomically most difficult genus of Nearctic unionids, notwithstanding Burch's (1973, 1975b) efforts at a partial resolution.

Because of these taxonomic problems, it is impossible to describe accurately the geographic range of the Ohio River Pigtoe except to state that it is (or was) widespread in the Mississippi and St. Lawrence basins.

Elliptio crassidens, Elephant Ear

Coker's (1919) account suggests that this species was relatively uncommon during the first great period of commercial shelling, but he was nevertheless able to mention "carloads" of Elephant Ear. Little more than a decade later the Ellis survey found one specimen, and 40-odd years after that the Academy found five. Fortunately, while declining rapidly in the Upper Mississippi River, *Elliptio crassidens* has survived impoundment of the Ohio, Green, and Tennessee Rivers rather well (Williams, 1969; Yokley, 1973).

One is reminded of *Fusconaia ebena* (above), especially because the only recorded glochidial host of the Elephant Ear is, again, the Skipjack Herring, whose Upper Mississippi migrations had essentially ceased by the time when Coker (1919) wrote and almost 20 years before Ellis' work--but have not in the other rivers mentioned. Also, the natural ranges of these two species were essentially identical.

There is little doubt that *Elliptio crassidens* faces extinction in the Upper Mississippi basin, not because of impoundment and associated habitat alterations, but because of the Koekuk dam, constructed 65 years ago for hydroelectric power. It is no longer possible to define the Elephants Ear's optimal habitat in the Upper Mississippi River.

Elliptio dilatata, Spike

Unlike the closely related *Elliptio crassidens* (above), the present species has a short, but diversified list of glochidial hosts (Exhibit 121), each of which is common to abundant and widespread in the Upper Mississippi River (Smith et al., 1971). Shimek (1888) had called *E. dilatata* "very common" in the Mississippi's Iowa reach, but Coker (1919) did not emphasize its abundance, and its proportions of Ellis' material (1.98%) and the Academy's (1.46%) are similar and small. This species favors established mussel beds, can be locally quite common, and exhibits some evidence of recruitment. These points indicate an animal that was savaged (by the commercial fishery from about 1890 through about 1915), has held its own for a very long time, and perhaps is now beginning to recover. That *E. dilatata* ranges so widely is hopeful: the Mississippi, Mobile, and intervening basins of the Gulf drainage (Coker, 1919; Grantham, 1969), plus the St. Lawrence basin of the Atlantic drainage (Goodrich and van der Schalie, 1932).

Obliquaria reflexa, Threehorn

This species was among the more widely ranging and, ironically, less populous mussels in the study area. The paradox is in keeping with other reports and may be related to the Threehorn's allegedly facultative glochidial parasitism. Theoretically, free-living larvae can spread far, wide, and rapidly, but unencysted glochidia are vulnerable to toxins and mechanical damage. The case for complete absence of a parasitic stage in *Obliquaria reflexa* is very strong because no hosts have been recorded (Fuller, 1974b); see *Anodonta imbecillis* and *Strophitus undulatus* (below).

The Threehorn's proportions of the Ellis and of the Academy samples are strikingly alike (3.22% and 3.20%, respectively); its uncommonness (see, also, Coker, 1919) has changed little if at all during recorded history. The Academy found evidence of the low degree of recruitment that would *a priori* be considered characteristic of a comparative rarity. *Obliquaria reflexa* must be regarded as a persistent and stable, but not abundant, member of the Upper Mississippi River naiad fauna.

The Threeridge ranges widely in the western Gulf drainage, including much of the Mississippi basin, and in the St. Lawrence River system of the Atlantic drainage.

This species' substrate tolerance is broad (occasional partly grown specimens were found in main channel sands).

Proptera alata, Pink Heelsplitter

Like so many species of no commercial value (save in the limited novelty trade), this animal assuredly suffered great accidental depredation at the height of the pearl button industry. Now it is uncommon in the Upper Mississippi River, but widespread.

This persistence probably is a result of at least two factors. First, *Proptera alata* is adequately insensitive to adverse water quality. Second, as is true of many Upper Mississippi mussels that are thin-shelled and/or small for much of their lives, this species' glochidia are parasites of the Freshwater Drum, *Aplodinotus grunniens* (Exhibit 121), which becomes infected when it preys upon gravid mussels. *A. grunniens* is the *only* known host of *P. alata*, but continues to range widely and populously in the Upper Mississippi River (Smith et al., 1971).

Proptera alata is an example of mutualism involving host and parasite, but this is not the limit of its role in the symbiont web. Like other naiades with large, flat, and smooth adult shells (notably *Lasmigona complanata*, the White Heelsplitter), the Pink Heelsplitter furnishes purchase for various ectosymbionts, which would otherwise secure little or no congenial substrate in the muddy type of streambed so often frequented by mussels. These epizoites include flatworms (Platyhelminthes:Turbellaria:Tricladida:(usually) Planariidae), bryozoans (Ectoprocta and, perhaps, Entoprocta), and leeches (Annelida:Clitellata:Hirudinea). This Heelsplitter contributes to the foodweb not only directly as a foodstuff for fishes, but also indirectly as a habitat for organisms that nourish fish and "lower" animals.

Proptera alata has a remarkable relationship to water mites (Arthropoda:Chelicerata:Acari:Hydrachnellae:Unionicolidae). In the Principal Investigator's experience, no mussel has harbored more mites per individual: scores of the presumed parasites occur in each clam, most of them on the anterior apposing surfaces of the demibranchs. According to Malcolm F. Vidrine (personal communication, University of Southwestern Louisiana), they ordinarily include some *Unionicola abnormipes* (Wolcott) and *U. fossulata* (Koenike), which are commonly encountered parasites typical of Lampsilinae, but the great majority are an undescribed species peculiar to the Pink Heelsplitter.

Proptera alata retains a great distribution in the Missisippi basin, which enhances its obvious ecosystematic value. The limits of its range beyond this basin are equivocal because of confusion of the Pink Heelsplitter with neighboring, similar *Proptera*.

Proptera laevissima, Pink Papershell

This species was 2.80% of Ellis' samples and only 0.73% of the Academy's, but this is a case of the figures' being deceiving. Because of concentrating on the main channel and its borders, the Academy rarely had an opportunity to collect where *Proptera laevissima* is most abundant, in the backwaters.

The Pink Papershell requires soft and easily penetrable, but nonetheless stable substrates; typically, it lives deeply buried in glutinous mud or muddy sand. That position is facilitated by the great breadth of the mantle margin at the apertures, where the extensible apposing margins form uniquely long "pseudosiphons", which permit communication with the water column from a position of uniquely deep burial. Paradoxically, this species was characteristic of navigation channel sands. Its low density, great mobility, and lengthy pseudosiphons apparently allow the animal to survive in the upper layer of moving bedload--and, perhaps, even to exploit this habitat, which is ultimately lethal for other species.

Waterway modification (i.e., impoundment, chiefly) apparently can thus be to this Papershell's advantage. Accordingly, there has been little or no restriction of its natural range, which is much of the Mississippi basin, plus additional basins to the east and west in the Gulf drainage. Exactly how far in either direction cannot be ascertained without resolution of extant confusion of *P. laevissima* with some similar species.

Like *Proptera alata* (above), *P. laevissima* depends chiefly upon the Freshwater Drum, *Aplodinotus grunniens*, for glochidial parasitism (see Exhibit 121).

Proptera capax, Fat Pocketbook

The Ellis survey obtained presumably living members of this species from areas of the Upper Mississippi River that are now included in numerous Pools (van der Schalie and van der Schalie, 1950). Thus, *Proptera capax* occurred rather widely in the Mississippi (and, presumably, elsewhere in its range) scarcely 50 years ago. However, the Academy's 1977 survey discovered no trace of *P. capax*, and recent records of living individuals are few (Appendix C).

The Fat Pocketbook's preferred habitat remains obscure, but it seems to involve lentic waters. Such habitats occur on the Upper Mississippi today, so one suspects that adverse water quality is responsible for this species' decline.

A fish that Shira (1913) intimated might be a host for glochidia of *Proptera capax* (see Exhibit 121) was not recorded in the Upper Mississippi River by Smith et al. (1971).

Clearly, even the most basic biology of this rare and Endangered mussel remains in doubt.

Proptera purpurata, Purple Pocketbook

The Purple Pocketbook is accepted for consideration in this report only because of a recent record of a live specimen taken from the Below Pool 27 reach by the Perry (1978) survey. *Proptera purpurata* ranges rather widely in the western Gulf drainage, including the Mississippi basin, but is clearly a southern faunistic element. As such, it should not be anticipated in the Upper Mississippi River, even though its one known glochidial host (Exhibit 121) is widespread and often abundant in many Pools (Smith et al., 1971) and suitable habitat is available. This species tolerates many habitats, but appears to favor slow waters and muddy stream beds. For example, it is locally abundant in the bayous of western Louisiana.

Leptodea fragilis, Fragile Papershell

The Fragile Papershell comprised 10.10% of Ellis' results in 1930 and 1931, but only 1.24% of the Academy's collection in 1977. This seemingly catastrophic drop in proportional representation is probably an artifact, for the same reason as in the case of *Proptera laevissima* (above). Additionally supporting the conclusion that *Leptodea fragilis* is *not* in any difficulty in the Upper Mississippi River is the great majority of juveniles in this species' totals for the study area (Exhibit 49). Also in this Papershell's favor is the abundance and wide distribution of its glochidial host, the Freshwater Drum (see *P. alata*, above). Further indicating the Fragile Papershell's success is its great range, which encompasses much of the Gulf drainage, from the Mobile basin of Alabama through the Mississippi basin into eastern Texas, plus the St. Lawrence basin of the Atlantic drainage. Finally, *L. fragilis* tolerates many streambed types.

Leptodea leptodon, Narrow Papershell

Once (and perhaps still) rather widely distributed in the Mississippi basin, *Leptodea leptodon* now is proposed as a nationally Endangered Species because of the poverty of recent records of live specimens. For example, apparently the

only study area record (at least from a reliable investigator) is Baker's (1903, 1928) for the Savanna Site in Pool 13. No specimens of any sort were taken by the Academy in 1977.

About all that is generally believed about this species' habitat is that it has been obtained from gravel riffles and rapids. No glochidial host, for example, has been recorded (Fuller, 1974b).

Compressed and elongate morphs of *Leptodea fragilis* (above) can be confused with the Narrow Papershell, about whose conchological discriminants there exists some uncertainty. Illustrations have been published by Burch (1973, 1975b), Johnson and Baker (1973), and Parmalee (1967).

Ellipsaria lineolata, Butterfly

This survey's records indicate that the Butterfly persists in the St. Croix River and in Rock Island District Pools, but is very rare or extirpated almost everywhere else in the study area. Similarly, this species' distribution has been curtailed elsewhere in the Mississippi basin, apparently the only one where it has been found.

Responsibility surely lies with declining water quality, perhaps extending well below the Twin Cities (see Parmalee, 1967, and Starrett, 1971, for similar findings regarding other streams) and with the commercial fishery, which damaged this species severely. The Butterfly was highly prized by the pearl button industry (Coker, 1919); it is unlikely that a single captured individual was spared.

Ellipsaria lineolata was only 0.41% of the Ellis collections scarcely two decades later; on the other hand, its former proportional representation is obscure (Coker (1919) obviously considered it a comparative rarity even then). In spite of the dramatic restriction of the Butterfly's range in the Upper Mississippi, it is startling to discover that, where it survives at all, the animal's numbers have scarcely declined over the past half century: Ellis' value noted above is almost exactly the Academy's for 1977 (0.46%).

The consistent recorded rarity of *Ellipsaria lineolata* has been influenced by the small number of females (J. F. Boepple *in* Coker, 1919); this claim is corroborated by the Academy's observations in 1977 that *every* female taken was *gravid* and that evidence of recruitment was marginal. One concludes that such reproduction as this species can accomplish must be extraordinarily efficient. This goal is aided by

Aplodinotus grunniens, the Freshwater Drum, chief of the Butterfly's glochidial hosts (Exhibit 121) according to Coker (1919). Mussels are a principal item in the Drum's diet (see *Proptera alata*, above): glochidiosis as a result of devouring larvigerous female *E. lineolata* doubtless occurs rarely, but effectively. The putative great age achieved by some Butterfly (Shimek, 1888) may be another factor in this species' unfaltering reproductive success.

Like most rare Upper Mississippi River mussels, *Ellipsaria lineolata* occurred only in rather rich seams or actual beds of mussels, on mud and/or gravel bottoms.

Truncilla truncata, Deertoe

Coker (1919) quoted this species as "very common", but it was only 1.13% of the Ellis collections, yet 2.52% of the Academy's. These data suggest that *Truncilla truncata* was badly damaged by the pearl button industry and has begun to recover very slowly since (the modern proportion of the Deertoe *may* be somewhat greater than it appears; see remarks about juvenile *Truncilla* in Appendix C).

This species' reproductive success probably is strengthened by its known glochidial hosts, the Sauger and Freshwater Drum (Exhibit 121), which are common and wide-ranging in the Upper Mississippi River (Smith et al., 1971); the predacious Drum must be especially valuable (see *Proptera alata*, above).

Also in the Deertoe's favor is its indifference to riverbed type; this is not strongly developed (*Truncilla truncata* is essentially a creature of the more dense mussel populations), but it has to be helpful.

This is a species struggling, but slowly overcoming the ongoing impact of former great adversity. That it continues to range widely in the western Gulf drainage, including much of the Mississippi basin, is additionally encouraging.

Truncilla donaciformis, Fawnfoot

Truncilla donaciformis was a distant second to the most commonly encountered species (*Amblema plicata*) during this survey. Adult Fawnfoot, least among Upper Mississippi River naiades (except for some *Carunculina parva*), are so small (rarely more than 2 cm in length) that the gauge of brail "hooks" used by the Academy crew collected them rarely; juvenile specimens comprised most of the 1977 records. Most of these *were* taken by brail, but only because of byssal threads.

During immediately post-larval life, many mussels have a byssus (or byssal thread) which serves to anchor them to stable substrata, thus minimizing disturbance by currents and mobile streambed materials. Observations by Sterki (1891a, 1891b), Frierson (1903), and Read and Oliver (1953) suggest that early juvenile byssal anchoring is a strategem of great importance among Nearctic naiades. On shifting-sand riverbed in Upper Mississippi River Pools, stable purchase is lacking, but on the surface of the moving sand often lies a layer of vegetable detritus. Post-larval byssi, entwined with plant debris, apparently form a matrix for juvenile mussels that rafts along the streambed and thus protects them from burial. Young Fawnfoot appear uncommonly able to ride this raft.

As the immediately post-larval juvenile matures, it loses its byssus (if indeed it had one) and commences an independently mobile stage. The fully free-living animal gradually becomes large enough to be so disturbed by buffeting currents that normal functions (nutrition, respiration) are interrupted or terminated, and the organism will die if it cannot stabilize itself. This is accomplished by burrowing out of the current and into the streambed--but, if this substrate is unstable, the mussel is doomed.

This partly conjectural account offers (1) an explanation of why juveniles, but not adult mussels, can be plentiful in maintained portions of the Upper Mississippi River navigation channel and (2) the novel notion that, under certain circumstances, the adult, rather than the larva or the juvenile, can be the weakest phase in the fresh-water mussel life cycle.

The Fawnfoot is widespread in the western Gulf drainage, including much of the Mississippi basin, and in the upper St. Lawrence River basin of the Atlantic drainage. This species' present success in the Upper Mississippi River is not surprising in view of this considerable geographic range. Moreover, like *Truncilla truncata* (above), *T. donaciformis* is a glochidial parasite of the Sauger and the Freshwater Drum, two widespread and common fishes.

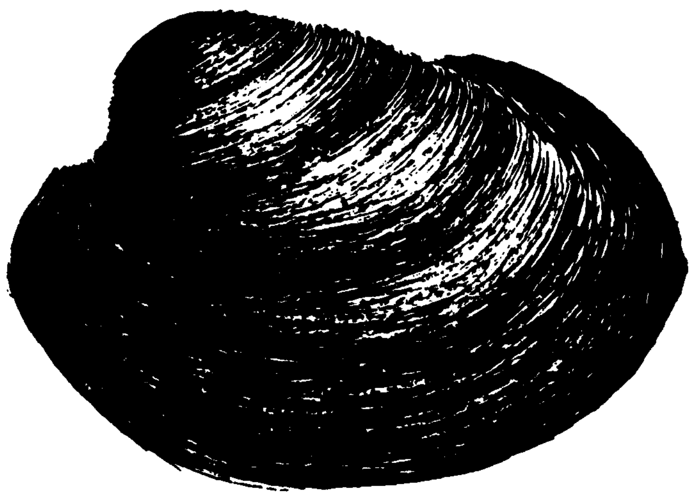
Obovaria olivaria, Hickorynut

The proportion of Hickorynut in the Upper Mississippi River fauna has scarcely changed during recent decades; both the Ellis and the Academy collections include somewhat more than 5% *Obovaria olivaria*. The only recorded glochidial host is the Shovelnose Sturgeon. Smith et al. (1971) reported that this fish is "taken occasionally from Lake Pepin to the mouth of the Ohio River." This distribution is very close to the

modern range of *O. olivaria*, but discovery of additional hosts probably is necessary to an explanation of this species' abundance. The Hickorynut ranges widely in the Upper Mississippi and St. Lawrence basins, and no grave decrease in original distribution apparently has been noted. The species' habitat tolerance is broad; for example, its adults were found by the Academy in navigation channel sand about as often as were those of *Proptera laevissima*.

Actinonaias carinata, Mucket

The Mucket's known glochidial hosts are numerous and varied (Exhibit 121); most of them remain common and widespread in the Upper Mississippi River (Smith et al., 1971). However, the Upper Mississippi population of *Actinonaias carinata* has dwindled drastically. (This species represented less than 1% of Ellis' and the Academy's living specimens, whereas once it was extremely important in pearl button manufacture.) This decreased abundance may be caused by declining water quality and/or excessive commercial harvest. This species may, in fact, now be below recruitment level. *A. carinata* prefers gravel streambed (Parmalee, 1967), but decrease of this habitat beneath impounded waters does not seem sufficient to explain its decline in the Upper Mississippi. This species is (or was) widespread in the Mississippi basin, in more than one portion of which its numbers have become greatly reduced.



Lampsilis higginsi (Lea)

Actinonaias ellipsiformis, Ellipse

This is one of the few mussels to which an entire paper (the van der Schalies, 1963) has been devoted. *Actinonaias ellipsiformis* ranges widely in the Upper Mississippi drainage and less so in certain Great Lakes drainages of the Upper St. Lawrence basin. It favors sand and gravel riffles in small streams, and, consequently, is very rare in the Upper Mississippi River. The only records are those of Grier and Mueller (1923) and of the Ellis survey a few years later (the van der Schalies, 1950); these are exclusively from Lake Pepin, where only one, circumscribed Site (Lake City Small Boat Harbor Entrance) was studied in 1977 by the Academy, which encountered the Ellipse nowhere in the Study Area. No glochidial host has been recorded (Exhibit 121), but some might be identified experimentally or in the field among sympatric fishes listed by the van der Schalies (1963). In Michigan, where *A. ellipsiformis* has been common, this species was recommended as Threatened because of its limited distribution and the increasing disappearance of pristine small-stream habitats (MDNR, 1976).

Ligumia recta, Black Sandshell

The proportions of Black Sandshell in the Ellis and the Academy samples are both beneath 1%. Coker (1919) implied that it had been more plentiful than it became in later decades, but it may be continuing at maintenance level. Fortunately, the glochidial hosts of *Ligumia recta* include several species that Smith et al. (1971) concluded are still common and widespread in the Upper Mississippi River (see Exhibit 121).

The Academy's experience of its usual modern habitat belies the "Sandshell" sobriquet; *Ligumia recta* was found almost exclusively in the company of plentiful mussels, sometimes in beds, but never on sand bars. Perhaps this is only another instance of a rare shell's naturally being found in greatest likelihood where mussels are commonest.

In favor of the Black Sandshell's continued survival in at least some portions of its natural range is its unusual vagility, which implies exceptional reproductive and adaptive capabilities. That range involves the St. Lawrence, Mobile, and Mississippi basins (Coker, 1919), plus smaller basins in Mississippi between the latter two (Grantham, 1969). Moreover, *Ligumia recta* is one of the few mussels to penetrate the Canadian Interior Basin (Clarke, 1973).

Ligumia subrostrata, Western Pondmussel

This species is admitted to the present document solely on the strength of Coker's (1919) figure of a shell expressly ascribed to "Mississippi River". It is highly unlikely that *Ligumia subrostrata* has ever been more than a stray in the Upper Mississippi mussel fauna. However, progressive habitat changes in response to continuing impoundment promise increasing incidence in the Pools of the slack-water, even ponded conditions that this species favors. Moreover, its known glochidial hosts (Exhibit 121) include fishes that are widespread and common in the study area (Smith et al., 1971). There is, then, good reason to suppose that the Western Pondmussel will become more important in the Upper Mississippi. Additionally supporting this supposition is the fact that, although (because of taxonomic problems) its correct geographic range is presently indefinite, it does range widely in the Gulf drainage, including the Mississippi basin; there are surely numerous avenues for its potential invasion of the study area.

Against this line of reasoning is the knowledge that *Ligumia subrostrata* is characteristic of the southern tier of states. That this animal was not found by the Ellis (van der Schalie and van der Schalie, 1950), Perry (1978), or Academy surveys may have been caused by its experiencing a northern terminal isotherm at the latitude of one of the lower Pools. Coker's (1919) record presumably is based on material collected near the old U. S. Bureau of Fisheries mussel propagation laboratory at Fairport, Iowa (i.e., in the reach that is now Pool 16). Thus, it is perhaps unwise to anticipate discovery of the Western Pondmussel farther upstream and especially in the Corps' St. Paul District.

Carunculina parva, Lilliput Shell

The Ellis survey collected this animal only in Lake Pepin (the van der Schalies' (1950) "Zone I"), where it comprised 0.09% of that survey's entire collection. Almost 50 years later the Academy found *Carunculina parva* more widespread and comprising 2.25% of its material.

One would reasonably infer an upsurge of the Lilliput Shell were it not for two points. First, about a century ago this species was known in the Upper Mississippi drainage from points as farflung as the Minnesota River at Ft. Snelling (Grant, 1886); the Winona, Minnesota, vicinity in what is now Pool 6 (Holzinger, 1888); and the Iowa River (Shimek, 1888). Second, the Academy's figure is the proportion of adults and juveniles; the latter seem to have been mostly ignored in

previous accounts. Like other mussel species, *Carunculina parva* has perhaps been entirely exterminated in the Minnesota and in the Twin Cities vicinity, but it is locally common in the Upper Mississippi River below. The discrepancies among extant data are surely caused by this species' merely having been overlooked, especially during recent decades, a period when the number of relevant investigators has declined.

The high number and proportion of juveniles evidence successful generation of the Lilliput Shell, but many of the Academy's records depend upon individuals from the main channel, where mussels are generally destroyed (see *Truncilla donaciformis*, above). Nevertheless, adult material is moderately common on a substrate of muddy sand in shallow, often slow-water areas close to shore. This habitat is typical of *Carunculina* elsewhere (see, e.g., Fuller, 1977b). In fact, this species is so well adapted to shallow-water life that it characteristically responds in a highly mobile fashion to changing water levels (Clench and Turner, 1956; Grantham, 1969; Isely, 1925; Murray and Leonard, 1962; Utterback, 1915-1916).

Serious taxonomic problems surround this genus and *C. parva* itself (Exhibit 2); therefore, there can be no fully accurate appreciation of the latter's original and current ranges (if they differ at all). It is safely stated that typical *C. parva* definitely occurs in the St. Lawrence basin and in much of the Upper Mississippi basin.

Glochidial hosts of the Lilliput Shell have been recorded (Exhibit 121), though the relevance of these data to the Upper Mississippi River is equivocal because the supporting experimental work was done hundreds of miles to the south.

Lampsilis teres, Yellow Sandshell

This species ranges throughout the Gulf drainage (including the Mississippi basin) from eastern Texas through peninsular Florida. It has suffered some reduction in much of its natural range, and in the Upper Mississippi River reduction has been severe. The Academy found the Yellow Sandshell alive in Pool 19 only, and there are few recent records outside that Pool, whereas *Lampsilis teres* was much more widespread around the turn of the century (Coker, 1919). It continued to be widespread and common through the time of the Ellis survey some 30 years later (van der Schalie and van der Schalie, 1950): Ellis' crew found *L. teres* common as far upriver as Lake Pepin. This is the mussel that was easily the most valuable to the pearl products industries, but it was never abundant at a given locality, even in those days (Coker, 1919).

As a shell both valuable and *relatively* uncommon, *L. teres* was certainly vulnerable to exorbitant commercial harvest, but the Ellis data show that, even if such devastation had occurred, the Yellow Sandshell rapidly recovered. (Indeed, Coker (1919) was confident that this would be a superior species for private commercial propagation.) It is clear, then, that *L. teres* was not crippled by overharvest--or by failure of its larval hosts. Several other fishes have been recorded (Exhibit 121), but Coker (1919) emphasized that Gars are much the dominant hosts of the Yellow Sandshell; the relevant Gars remain adequately plentiful in the Mississippi Pools (Smith et al., 1971). The real cause of this Sandshell's decline (in especially the St. Paul District) probably has been the impact of gradually deteriorating water quality. The decline of *L. teres* has a memorable numerical value: among the 38 modern species-group taxonomic concepts that are represented in the Ellis collections the Yellow Sandshell ranks first in abundance (only *Leptodea fragilis* is even somewhat close) and is tied (by *Amblema plicata* and *Truncilla donaciformis*) for first place in terms of ranging throughout the "Zones" set up by the van der Schalies (1950); contrasting sharply with this dominion is the Yellow Sandshell's record in 1977, when it made up only 0.21% of the Academy's samples, occurred in only one Pool (as noted above) and ranked 25th of 32 species in terms of abundance in the entire study area.

These changes in relative and absolute abundance do not seem to have altered this species' habitat preference, however. *Lampsilis teres* still frequents sandbars and (see Coker, 1919) is a rarity in the "principal mussel beds". At Turkey and Hog Islands (of the "Green Bay" Sites in Pool 19) youthful Yellow Sandshells were found on muddy sandbars in shallow backwaters. This observation shows, also, that this species is quite capable of successful reproduction in suitable circumstances. One is reminded of Coker's belief that *L. teres* would do well if artificially propagated.

Lampsilis higginsi, Higgins' Eye

An uncommon species even early in this century (Coker, 1919), Higgins' Eye shortly thereafter became increasingly rare: both the Ellis and the Academy surveys found very few animals, and there is only a scattering of recent and localized historical records. The literature includes no statement that the animal was ever "abundant" anywhere. There are no unequivocal indications that, except in the uppermost Mississippi River Pools, sedimentation and/or chemical pollution has reduced populations of *Lampsilis higginsi*. It seems more likely that excessive commercial harvest brought this comparative rarity below maintenance level throughout most of its original range in the Upper Mississippi River.

Capture of a larvigerous female at the Hudson Site shows that fertilization and gravidity can be expected in water of adequate quality, and the population structure of *Lampsilis higginsi* in the East Channel of the Mississippi River at Prairie du Chien, Wisconsin, is evidence of recruitment. Moreover, the recorded glochidial hosts--Sauger and Freshwater Drum (Exhibit 121)--are plentiful and widespread in the Upper Mississippi River (Smith et al., 1971). Ironically, in view of its notoriety, Higgins' Eye is *the* jeopardized Upper Mississippi mussel species that is well suited to a recovery program, because of the probably adequate volume of extant knowledge that would be necessary to such an undertaking and because of the availability of breeding stock at Prairie du Chien. No refugial populations of other federally Endangered species are known in the Mississippi.

HOOKAH diving at Hudson revealed *Lampsilis higginsi* beneath about 10 to 15 ft of water in mud with an admixture of gravel and stones. The best Hudson mussel population begins immediately below the railroad bridge, where the St. Croix River narrows suddenly. The acceleration and turbulence of the water as it passes through this constriction probably increase its aeration. This is surely advantageous to the mussels immediately downstream, including Higgins' Eye. It is not known whether *L. higginsi* requires unusually oxygen-rich water. Although the river floor at Prairie du Chien is similar to that just described, the East Channel there does not hydrodynamically resemble the St. Croix where this species is found. The "critical habitat" of *L. higginsi* probably includes few or no factors that are not among those required by almost any Upper Mississippi mussel.

The range of Higgins' Eye cannot be accurately assessed, because of the taxonomic problems surrounding it. The complex to which *Lampsilis higginsi* belongs once ranged widely in the Upper Mississippi basin, but all nominal members have suffered distributional reductions (see Imlay, 1972a).

Lampsilis radiata siliquoidea, Fat Mucket

This subspecies and its relatives are *the* success story of Recent adaptive radiation among Nearctic naiades. Only in the Pacific drainage is this complex *not* represented in North America (Clarke, 1973). Its members exploit almost any permanent waterway.

Broad habitat tolerance is characteristic of *Lampsilis radiata siliquoidea* in the Upper Mississippi basin (see Wilson and Danglade, 1914), but the Fat Mucket's range in the Upper Mississippi River has become reduced during recent decades.

Both the Ellis and the Academy surveys found it no farther south than Pool 10; the subspecies probably is a northern one (at least with respect to the mainstem Mississippi). The correct natural range of the Fat Mucket cannot be ascertained, because of taxonomic problems (see Exhibit 2).

The upper Pools of the St. Paul District offer most unionids little acceptable habitat. Nevertheless, *L. r. siliquoidea* can survive rather well locally, as in Lake Onalaska (i.e., lower Pool 7) near La Crosse, Wisconsin (Marking and Bills, 1977), where it is common in non-channel habitats, notably shallow-water areas near islands (Havlik, 1977b).

Because its investigation was limited to the navigation channel and immediate environs, the Academy perhaps overlooked most optimal Fat Mucket habitats; significantly, living *Lampsilis radiata siliquoidea* were not secured at the Hudson RR Bridge Site until pollywogging was undertaken in unbrailable, muddy sand shallows.

It is impossible unequivocally to account for the decline of Fat Mucket in the 1977 study area. Water quality deterioration and commercial harvest probably are at fault. However, poor opportunities for glochidiosis cannot be the problem: of the many species of relevant fish hosts (Exhibit 121), almost all persist essentially unabated in the Upper Mississippi (Smith et al., 1971).

Lampsilis ovata ventricosa, Pocketbook

This subspecies made up 4.04% of the Ellis survey's collections, but only 1.27% of the Academy's; the Pocketbook was in 1977 a regularly encountered shell in many Pools, but not an abundant one. Byssally attached to the brail, juvenile *Lampsilis ovata ventricosa* were collected in much of the study area; the animal reproduces effectively, probably because most of the recorded glochidial hosts (Exhibit 121) persist so successfully in the Upper Mississippi River (Smith et al., 1971). The Academy survey found that this subspecies' role in the Upper Mississippi naiad fauna is little changed from the circumstances reported long ago by Coker (1919); it remains a shell that recruits itself poorly, but is maintained because of tolerance of a large variety of streambed types. Because of taxonomic problems (Exhibit 2), the natural range of the Pocketbook cannot be fully determined.

Dysnomia triquetra, Snuffbox

Having been found in only a few reaches of the Upper Mississippi River that can be equated to modern Pools, the Snuffbox obviously is only an occasional stray into the main stem River (Appendix C). The Academy found no trace of it i 1977. Like its congeners, *Dysnomia triquetra* is adapted to riffles, but its even minor occurrence in the Upper Missis-sippi, where riffles have never been commonplace (even befor blasting of "white-water" riverbed in the interest of naviga tion), suggests that this species exhibits a breadth of habi tat tolerance that is atypical of its genus. On the other hand, the failure of the Snuffbox to exploit the Upper Missi sippi may have been caused by a dearth of best habitat and o physiologically congenial glochidial hosts (none is known (Fuller, 1974b)). The animal is much the most geographicall farflung of *Dysnomia*: it is widespread in the Upper Missis-sippi basin and in the upper St. Lawrence River basin of the Nearctic Atlantic drainage (Johnson, 1978).

The unusual survival of this *Dysnomia* suggests that the Upper Mississippi River could yet recover an environmental quality such that it could support Riffle Shells (*Dysnomia*), especially the Snuffbox, in terms of water quality; the prim tive soft-tissue anatomy of *D. triquetra* (Ortmann, 1912) correlates well with the notion that this species has a some what broad environmental tolerance.

Arcidens confragosus, Rockshell

Coker (1919) wrote that this species is "rare but widel distributed", and about half a century later the Academy's 1977 findings agree. The difference between the Rockshell's relative abundance in the present study (0.53%) and the findings of the Ellis survey (0.10%) is small; it could be caused by the haphazard collection of just a few specimens i either study and must be considered trivial. The historica rationale behind the vernacular name Rockshell is evidenced the Academy crew's finding *Arcidens confragosus* on rocky riv bed in Savanna Bay at the Savanna Site (Exhibit 87). This s cies appears to have persisted essentially unchanged despite environmental vicissitudes. Its known hosts (Exhibit 121), phylogenetically diversified group, include several fishes o continued success in the Upper Mississippi River (Smith et a 1971). The Rockshell is rightly named, but it occurs in man niches and exploits divers larval hosts; its survival is a result of practical, varied, generalized adaptation. Signif icantly, it is widespread, but rarely abundant, in much of t Gulf drainage, including the Mississippi basin.

Lasmigona complanata, White Heelsplitter

The Academy found this species to be somewhat more common and widespread than had the Ellis survey, but the difference between these surveys' results is minute. The White Heelsplitter, like the Rockshell (above), is a good example of characteristic anodontine adaption: it exploits slow-water and sedimentary areas. Impoundment of the Upper Mississippi River for about the last 40 years has increased the anodontine habitat, and the relevant genera, especially thin-shelled *Anodonta*, can be expected to benefit. The Academy's discovery of a juvenile *Lasmigona complanata* in backwater shallows at the Hog Island Site, although no adults were brailed there, supports this point. The White Heelsplitter's recorded fish hosts (Exhibit 121) are commonly encountered and widely distributed among Upper Mississippi Pools (Smith et al., 1971). A comparative rarity in the Upper Mississippi River, *L. complanata* is now restricted essentially to mussel beds, although its young occur elsewhere. This species tolerates acidic small streams (Jewell, 1922), plus lakes in the upper Mississippi basin (Wilson and Danglade, 1914). The White Heelsplitter's habitat tolerance is very wide, even though it is hardly commonplace in the Upper Mississippi River. Its original natural range was the Mississippi basin, but *L. complanata* invaded the St. Lawrence basin of the Atlantic drainage, as well as the Canadian Interior Basin (Clarke, 1973).

Lasmigona costata, Fluted Shell

This is not a typically large-stream species, but it is admitted to this report on the strength of the few known study area records. The Fluted Shell occurs in the upper Mississippi basin, plus the upper St. Lawrence River basin of the Atlantic drainage (Goodrich and van der Schalie, 1932) and the Canadian Interior Basin (Clarke, 1973). The *ecological* range of this species, on the other hand, is not so well understood; relevant knowledge for the Upper Mississippi River, of course, is almost nil. *Lasmigona costata* favors shallow-water gravel riffles. Its only recorded glochidial host is the Carp, which is "an abundant and important fish throughout the (Upper Mississippi) river" (Smith et al., 1971). Were the physical habitat more suitable, no doubt this mussel would be better represented in the study area.

Lasmigona compressa, Creek Heelsplitter

Like its congener *Lasmigona costata* (above), this species is almost entirely restricted to smaller streams. This constraint is the more rigid in the case of *L. compressa*. The

putative records of the Creek Heelsplitter in Appendix C may be the first for the mainstem Mississippi (the Principal Investigator has not had an opportunity to examine the relevant voucher material). Other than the small-stream predilection, this species' habitat tolerance is catholic (Clarke, 1973). No larval host has been recorded (Fuller, 1974b). The natural range is vast: upper Mississippi basin, St. Lawrence and Hudson River basins of the Atlantic drainage, and the Canadian Interior Basin (Clarke, 1973). Hermaphroditism and rarity of males are prevalent in *L. compressa* (Clarke, 1973): "Hermaphroditism may be an adaptive character for life in headwater streams and for passive introduction into previously unoccupied areas."

Alasmidonta marginata, Elktoe

Bones of Elktoe are still occasionally found in the study area, but it appears that no living material has been taken since the Ellis survey decades ago secured a few individuals below Lake Pepin in Pool 4 (van der Schalie and van der Schalie, 1950). *Alasmidonta marginata* is doubtless nearly or quite extinct in the Upper Mississippi River, but, as yet another species for which smaller streams are more appropriate (e.g., Parmalee, 1967), it has never been an important mussel in these waters. Long before heavy urbanization of the Mississippi valley, Shimek (1888), for example, considered the Elktoe "not common" in the Mississippi and other rivers of the upper basin. The possible disappearance of this species from the Upper Mississippi is thus not a great loss, especially because it has (or had) a wide range in the basin (Parmalee, 1967) and is thought to occur in the upper Susquehanna River system of the Atlantic drainage (Johnson, 1970), where the very closely related Brook Floater, *A. varicosa* (Lamarck), is widespread (Fuller, 1977b). The "superspecific" gene pool to which *A. marginata* belongs is not yet in great jeopardy. Several host fishes of Elktoe glochidia have been identified and/or implicated (Exhibit 121), but the information has little practical value in the Upper Mississippi. Nothing appears to be known about this species' other symbionts, perhaps because the pristine character of its preferred habitat discourages microinvertebrates, such as flukes and water mites: "good current, a sand or gravel bottom and a depth of several inches to two feet" (Parmalee, 1967).

Alasmidonta calceola, Slippershell

Apparently, the only record of *Alasmidonta calceola* in the Upper Mississippi River is the one published by Grier and Mueller (1922-1923) for Fountain City, Wisconsin (Pool 5A).

The van der Schalies (1950) correctly regarded the Slippershell as a characteristically small-stream species. This environmental predilection probably is closely related to the natures of this species' larval hosts: the only two identified or implicated are *Etheostoma nigrum* Rafinesque, Johnny Darter (Percidae), and *Cottus bairdi* Girard, Mottled Sculpin (Cottidae) (J. P. E. Morrison *in* Clarke and Berg, 1959). These two fishes are neither common nor widespread species in the Upper Mississippi (Smith et al., 1971). *A. calceola* can sensibly be regarded as an only occasional stray into the present study area and as an animal of little consequence to this report. The Slippershell is characteristic of the northern tier of States, including upper portions of the Mississippi basin and of the St. Lawrence River basin in the Atlantic drainage. The Fountain City record is consistent with this distribution. Future investigators should especially anticipate *A. calceola* in Pools of the Corps' St. Paul District.

Simpsoniconcha ambigua, Salamander Mussel

Perhaps there is no species of Nearctic fresh-water mussel that is at present more mysterious than this one. Few living specimens have been seen during recent decades, and there have been no Upper Mississippi River records since the Ellis survey dredged a single animal almost 50 years ago. Nevertheless, Howard's (1914c, 1915, 1951) papers provide insight into this species' habitat and reproduction, which are unique and inextricably bound together.

The only known host of the Salamander Mussel's glochidia is the Mud Puppy (Conant's (1958) vernacular name), *Necturus m. maculosus* Rafinesque. This aquatic salamander inhabits interstices beneath rocks on the streambed, and it is precisely this unusual unionid habitat where *Simpsoniconcha ambigua* has most plentifully been found. *N. m. maculosus* has suffered accelerating range-restriction of late years, presumably because of adverse water quality and the hastening disappearance of shallow rocky areas from most streams, especially the larger ones, which are favored by the Mud Puppy. This animal's decline may be the *chief* cause of the increasing rarity of the Salamander Mussel.

As far as the preferred, rocky habitat is concerned, the Salamander Mussel strongly resembles *Cumberlandia monodonta*, the Spectacle Case (above); perhaps *Simpsoniconcha ambigua*, also, may prove to inhabit wingdams. In the Upper Mississippi River, at least, the nearly complete destruction of lithic habitats surely threatens both species.

Once rather widely recorded in the Mississippi basin, *Simpsoniconcha ambigua* seems now to be at the edge of extinction. The Academy's 1977 survey found no trace of the animal. However, this surveillance did not employ the major grappling devices used by the Ellis survey. It is possible that the Salamander Mussel remains alive in the Upper Mississippi River. The possibility poses an environmental and legal problem for the Corps, whose channel maintenance often includes disturbance of rocky riverbed, especially in the Rock Island District. The Principal Investigator recommends that the Corps institute a program designed to evaluate the status of *S. ambigua* in the Upper Mississippi River.

Simpsoniconcha ambigua occurs on a rock-by-rock basis: 200-odd individuals may live in the riverbed beneath a single rock, or none may occur for miles within an area. Accordingly, this species' occurrence is sporadic, and failure to find it is likely. An accumulation of negative evidence should not dissuade an investigator from further search.

Anodontoides ferussacianus, Cylinder

This mussel favors "small, quiet streams, on a sand or fine gravel bottom in shallow water" (Parmalee, 1967). There are almost no records of its occurrence in the Mississippi River proper (Appendix C). There is abundant information about its glochidial hosts, for example, but this has little practical bearing on this report. The Cylinder is widespread in the upper Mississippi basin (*ibid.*), the upper St. Lawrence basin (Goodrich and van der Schalie, 1932), and the Canadian Interior Basin (Clarke, 1973). Harman (1970b) recorded the Cylinder from the upper Susquehanna River system of the Atlantic drainage. The animal would be a welcome addition to the Mississippi River fauna because of its obvious success, but it is an almost obligately small-stream creature. With the exception of *Catostomus commersoni*, the White Sucker, known host fishes (Appendix D) are rare and/or accidental in the Upper Mississippi River or are restricted to its headwaters (Smith et al., 1971).

Anodonta suborbiculata, Flat Floater

Not mentioned by the van der Schalies (1950) in their study of the fresh-water mussels of the Mississippi River, *Anodonta suborbiculata* has recently been discovered more frequently in the Upper Mississippi River. These discoveries are part of an apparent resurgence of this species during about the last decade. This resurgence is caused by the increasing impoundment of large streams throughout the eastern

United States. The Flat Floater is apt to be found in deep viscous mud beneath moderately shallow waters (M. F. Vidrine, personal communication, University of Southwestern Louisiana); this habitat is increased by impoundment. Enormous populations of *A. suborbiculata* have been discovered in Tennessee River lakes and in the Atchafalaya Basin of Louisiana. These discoveries were facilitated by draw-down or other low-water conditions. This Floater favors waters deeper than those ordinarily examinable by pollywogging. This point should have been clear as a result of Wheeler's (1918) observations, but it has come as a surprise to modern investigators, who, armed with this novel insight, have at last begun successfully to search specifically for this animal. The combination of improved expertise and increased optimal habitat has led to regarding *A. suborbiculata* as a rather common species, whereas only a few years ago it was considered a rarity, perhaps in jeopardy.

The Flat Floater is a vigorous, opportunistic, successful invader and colonizer where favorable habitat is available. *Anodonta suborbiculata* can be considered widely established, but largely undiscovered, and further Upper Mississippi records should be anticipated, especially throughout the river below Pool 7. The as yet unknown northern terminal isotherm doubtless lies somewhere above La Crosse, Wisconsin, but at present there is no reason to suppose that this species cannot penetrate farther upstream than Pool 8. Certainly, host fish availability poses no problem (see Exhibit 121 and Smith et al., 1971).

Anodonta imbecillis, Paper Floater

This is possibly the most enigmatic of Nearctic naiades. The animal falters where it theoretically should not and survives where it equally should not. Its structurally low density argues that *Anodonta imbecillis* must always appear in the finely divided sediments and sluggish hydrodynamics of sloughs and other backwaters throughout its geographic range, but the species does not always appear. On the other hand, it "should not" occur among the many species that populate rich mussel beds in regularly flowing and deep waters--but it does.

The Paper Floater's geographic and ecological ranges defy easy analysis, and this difficulty may be related to the fact that it is, at least allegedly, among the few fresh-water mussels in North America that exhibit facultative larval parasitism (Howard, 1914d; Clark and Stein, 1921; E. Allen, 1924). There is additional evidence that *A. imbecillis* is hypertachytictic (Heard and Guckert, 1971). The recently described sexual vagaries of populations of this species from a geographically restricted area (Heard, 1975b) suggest that the Paper

Floater uses reproductive strategies that vary according to the vicissitudes of its immediate environs. This may account for its being unpredictably more or less abundant in seemingly favorable habitats. That *A. imbecillis* can be glochidially parasitic (Tucker, 1927, 1928) must be added here. *Semotilus atromaculatus*, the Creek Chub, and *Lepomis cyanellus*, the Green Sunfish, have been identified as host fishes (Clarke and Berg, 1959, and Tucker, 1927, respectively).

Records of the Paper Floater in the Upper Mississippi River are farflung, but spotty (Appendix C), no doubt partly because this animal can be tiny and because its preferred soft-bottom backwater habitat is often inadequately searched. The Academy found this species in the St. Croix River and in several Upper Mississippi Pools, especially Pool 19. The range of *Anodonta imbecillis* is almost as great as that of the *Lampsilis radiata* complex (see *L. r. siliquoidea*, above). The Paper Floater extends almost throughout the Atlantic and Gulf drainages of the United States from the Delaware River basin in Pennsylvania (Fuller and Hartenstine, MS) south into peninsular Florida and thence west into Texas. *A. imbecillis* is widespread in the Mississippi River basin. Its range in Mexico (if any) is not understood by the Principal Investigator.

Anodonta grandis, Giant Floater

There appears to have been a slight decline (1.2%) in this species' proportional representation since the Ellis survey. This is unexpected because the Giant Floater prospers under impoundment conditions and because Ellis' work was conducted in the pre-9-Foot Channel era. The Academy's necessary concentration upon the navigation channel and relative failure to study backwater areas favored by *Anodonta grandis* probably account for this irony. Nevertheless, this species was encountered widely (and sometimes plentifully) in the study area. Moreover, it occurred on almost any streambed type, and there was unequivocal evidence of ongoing, recent recruitment.

The Giant Floater's success is reflected in its geographical distribution, also. Its range cannot be defined with precision because of taxonomic problems, but the "*grandis*-complex" is represented in the Gulf drainage, including the Mississippi basin, from the Appalachicolan region west into Mexico. It ranges widely in the Mississippi basin and has penetrated the St. Lawrence River system of the Atlantic drainage (Goodrich and van der Schalie, 1932) and the Canadian Interior Basin (Clarke, 1973). This distribution surely is influenced by redundance of host fishes (Exhibit 121); *A. grandis* is credited with more glochidial hosts than are recorded for any other Nearctic mussel (Fuller, 1974b).

Strophitus undulatus, Strange Floater

This is another case in which taxonomic problems (Exhibit 2) interfere with proper understanding of a species, though much is known about its genus. The most striking feature is the enormous geographic range; *Strophitus* occurs almost throughout the Atlantic and Gulf drainages of the United States, including the Mississippi basin, as well as much of the Canadian Interior Basin (Clarke, 1973). Only the ranges of *Anodonta imbecillis* and the *Lampsilis radiata* group would challenge this one. This range may be facilitated by this species' alleged facultative dependence upon larval parasitism; however, a few host fishes have been recorded (Exhibit 121). In any case, *S. undulatus* has apparently never been common in the Upper Mississippi River; it is another characteristically small-stream animal. The Academy found it widespread, but sporadic and always very rare. Its substrate tolerance is catholic.

Particle Size Distribution

Streambed samples were taken by Ponar dredge at many localities in the study area. It was hoped that analysis of particle sizes and their proportions in these samples would contribute to understanding of mussel occurrence in relation to streambed types. Early in the field work it became apparent that a much more extensive research program would be needed in order to provide a meaningful amount of information. Consequently, this type of sampling was discontinued, and the time saved was applied to other, obviously productive aspects of the project. Note, however, that gross characterizations of the riverbed occur in the Site discussions wherever, in the Principal Investigator's opinion, they improve understanding of mussel distribution.

Later, streambed sampling was resumed among the "Green Bay" Sites in the hope that particle size distribution analysis of the several obvious substrate types (sand, gravel, mud, etc.) in that reach might prove useful. Unfortunately, the analyses revealed little more than that the samples consisted of sand, gravel, mud, etc.

Samples were taken at five locations: Shokokon Slough opposite the head of the Turkey Island Site, main channel at the head of that Site, main channel border off the head of Dallas Island, main channel off Dallas Island, and main channel border off the head of Hog Island. The results of the five analyses are on file in the Division of Limnology and Ecology at the Academy.

IMPACT OF CORPS OF ENGINEERS DREDGING

UPON UPPER MISSISSIPPI RIVER MUSSELS

A major goal of this report is to evaluate the impact on mussel populations of dredging and associated activities that are conducted by the Corps of Engineers in order to maintain the 9-foot navigation channel. Dredging related to construction was involved at a minority of the study Sites and is discussed separately near the end of this section. All study Sites had a history of dredging and/or were scheduled for dredging.

"Dredging" can be subdivided into three types of activity, each with its characteristic form of potential adverse impact on mussels: (1) the removal and transport of material from the riverbed, (2) the suspension of material in the water column peripheral to actual dredging, and (3) the deposition of dredged material.

The removal of material from the riverbed commonly involves the simultaneous removal of macrobenthos, including mussels. This removal subjects mussels to possible destruction caused by dredging equipment and subsequent turbulent transport through pipes to a new location. The extent of this destruction could be indicated by the occurrence of damaged shells at dredged material deposition sites. During the Academy field study, damaged shells were found in some of the numerous "spoil banks" examined. Some of these shells could have been washed onto the banks during periods of high water. However, the high correlation observed between number of damaged shells and frequency of past dredging suggests that many of the damaged shells had been dredged.

The second condition associated with channel maintenance dredging that can adversely affect fresh-water mussels is the suspension (and/or resuspension) in the water column of materials disturbed (but not engulfed) by the dredge, plus ensuing turbidity and sediment migration. Turbidity reduces light penetration into the water. This decreases primary productivity, reducing the availability of microorganisms upon which mussels feed. Suspended fine particles causing the turbidity can interfere with feeding and respiration by clogging the gills. Increased turbidity occurs naturally during periods of high water, which may last much longer than turbidity caused by channel dredging. Because mussels appear to be adversely affected by these periods of natural high turbidity rarely if at all, it is unlikely that turbidity caused by short-term dredging would cause heavy mortality.

Migration of sediments disturbed by dredging could be a problem if it resulted in heavy redeposition on mussels. That such damaging redeposition does not occur frequently is suggested by the Academy's occasional observation that mussel populations occurred in channel borders close to areas that had been frequently dredged over the years. The most dramatic example from this study is the discovery at Hudson, Wisconsin, of living *Lampsilis higginsi* in the St. Croix River within a few meters of an area that had been dredged within the life of the specimens.

Another problem associated with increased turbidity and sediment migration can occur when the resuspended sediments contain toxic materials, such as heavy metals. Toxic materials lying undisturbed in the streambed usually cause mussels little or no direct damage. However, the exposure of a living organism to toxins is dramatically increased when they are released from the riverbed into the water column and distributed downstream by the current. This can result in the contamination of relatively clean waters by toxic materials released by dredging at a distant site. Such release of toxic materials may occur during channel dredging. Assessing the extent of this problem would require an investigation designed differently from the present study.

The third aspect of dredging is the deposition of dredged material, which can affect mussels in four ways. The most obvious is the direct deposition of dredged mussels onto land, which is fatal. The second occurs when disposal is a two-step process. Dredged material is transported close to shore by barge, dumped in the shallows, and then redredged onto land. It is very hard for a crane to skim the material from any inshore mussels thus buried. The usual result is that they either remain buried or are dredged onto land, both possibilities leading to death. The extent of destruction of mussels dwelling inshore that is caused by this two-step disposal cannot be accurately assessed--either the mussels are buried or their dead shells are difficult to distinguish from shells that had been either directly dredged onto land or deposited during high water.

A third problem related to the deposition of dredged materials is the slippage of these materials back into the water from sites that are poorly graded and/or located too close to the river. Some of the Sites studied by the Academy exhibited this problem, and few living mussels were found in loose material in the shallows close to a decaying "spoil bank". It is not possible to know how much mussel mortality has been occasioned by this gradual form of burial, although there surely has been some. A recent study (Marking and Bills, 1977) suggests that this type of mortality has been

overestimated. Their study demonstrates that mussels are far better able to survive burial than had previously been thought.

A fourth case illustrating problems that can be caused by the deposition of dredged materials is the filling-in of backwaters. This can have ramifications beyond the burial of mussels. Backwaters offer prime nursery and breeding ground for unionids and their host fishes (the rich shallow-water mussel populations at the Hog Island Site are an excellent example) and thus provide a reservoir of larvae, some of which contribute to populations farther afield. Destruction of a backwater population is not only a loss in itself, but also a loss of mussel resource to surrounding waters. Although the Academy observed no such destruction caused by the Corps, it is highly unlikely that Corps dredging has never damaged backwater breeding grounds.

The impacts discussed so far have resulted from dredging involved in channel maintenance; a related activity affecting mussels is dredging as a part of construction projects. The Academy's field work included few opportunities to examine construction sites. However, on the basis of the available observations, several tentative statements can be made concerning construction-related dredging. First, in deep-water areas of the main channel, where mussel beds can and do occur, construction dredging is a potential threat. Second, this threat increases in the main channel borders, where beds are more common, especially along stabilized shore. Third, the threat exists in the larger side channels, where beds also occur, and in backwaters, which often are important mussel nursery grounds. Fourth, construction dredging can involve longer-term disturbances, because construction projects can last for months or years. Conditions discussed earlier, such as turbidity and release of toxic materials, may have more serious consequences when they persist over longer periods of time.

It was concluded from the present study that channel dredging and associated activities of the Corps in the Upper Mississippi River have only a minor impact on fresh-water mussels, including the legally protected species. There are known instances of adverse impact on legally protected species, such as the destruction of *Lampsilis higginsi* in the Mississippi River East Channel at Prairie du Chien. However, no further such instances were in unequivocal evidence during the Academy's study, with one exception: the single young *L. higginsi* identified in material dredged in 1977 at the Brownsville Site. The rockdwelling habits of *Cumberlandia monodonta* make it especially vulnerable to dredging. Inadvertent destruction of this animal by Corps dredging and other forms of riverbed disturbance will continue unless this species'

individual populations are sought out and thereafter avoided.

The conclusion regarding the impact of Corps dredging on mussels is based on the available evidence, which is circumstantial, and not all potential impacts of Corps dredging can be adequately quantified. However, the Principal Investigator believes that the evidence in support of this conclusion is highly persuasive. The impact on mussels by Corps channel-maintenance and other dredging should continue to be minor if the careful planning that increasingly characterizes Corps decisions about dredging continues in the future.

SUMMARY

The Academy of Natural Sciences of Philadelphia has studied the historical and present geographical distributions and the ecologies of freshwater mussels in the Upper Mississippi River basin, plus the possible effects on these mussels of dredging conducted by the United States Army Corps of Engineers. This information for legally Endangered and other unionid species is required so that careful planning can minimize the impact on mussels of channel-maintenance and other dredging.

The field study was conducted from mid-July through mid-November 1977 at Sites in the navigable portions of the Minnesota, St. Croix, and Upper Mississippi Rivers. There were three, one, and 42 Sites in these rivers, respectively. In addition to the formal Sites, the Academy cursorily surveyed more than a dozen additional locations during 1977. Each channel-maintenance site was selected by the Corps because of its history of high-frequency dredging and/or because of the suspected presence of legally Endangered mussels. The Sites were surveyed with appropriate techniques, such as brailing, HOOKAH diving, and pollywogging.

The Academy collected and examined 8,502 living mussel specimens; hundreds of additional adult Threeridge (*Amblema plicata*) were found. This species dominated the mussel fauna throughout the study area, as indicated in numerous recent studies by other investigators, and its abundance was only estimated at some Sites.

The next to the most numerous mussel was the Fawnfoot, *Truncilla donaciformis*, which nevertheless was considerably less abundant than the Threeridge. The Fawnfoot population would have appeared even smaller if the identifications had not included juveniles. The identification of juveniles also revealed the unexpected finding that the adult, not necessarily the larval or the juvenile stage, can be the weak link in the mussel life cycle: juvenile Fawnfoot were commonly secured in the main channel, where adults of almost all species cannot prosper because their infaunal existence means that most of them would be buried by shifting sand.

Juvenile data can also provide insight concerning a species' reproductive capability. It is encouraging that juveniles of many species *were* found. Also, the population structures of many mussel species gave evidence of recruitment.

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FRESH-WATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE) OF THE UPPE--ETC(U)
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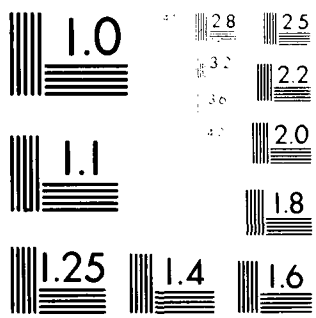

MICROCOPY RESOLUTION TEST CHART

Mussel populations of the lower Minnesota River, which had been diversified and abundant in the late 19th Century, appeared to be completely extinguished in 1977. Historical changes in mussel populations of the lower St. Croix cannot be reliably assessed because of the inadequate quantity of published locality records. However, it is clear that 1977 records for the relevant Site studied by the Academy (i.e., Hudson RR Bridge) compare very favorably with the historical ones for the entire river. The Upper Mississippi River had an abundant and diversified mussel community in the late 19th Century, before the heavy losses caused by the pearl button industry during the period from about 1890 through about 1920. In 1977, there were unquestionably far fewer mussels than there had been in the late 19th Century. Mussels were nearly or fully extinguished in the St. Anthony Falls Pools and Pools 1 through 3. Limited recovery occurred in Pool 4. The fauna improved increasingly through the Pools below.

Although the absolute abundances of most (and probably all) mussel species in the Upper Mississippi River basin have declined during the last 75 years, relative abundances have frequently stayed much the same. One of the exceptions to this trend is *Quadrula quadrula*, the Mapleleaf, which is a dramatic example of an animal that has exploited the impoundment habitat.

An unfortunate number of species is in decline and facing extinction in the Upper Mississippi drainage. Conspicuous examples of mussels whose ranges and numbers have been greatly reduced are *Tritogonia verrucosa*, Buckhorn; *Plethobasus cyphyus*, Bullhead; and *Elliptio crassidens*, Elephant Ear. These animals are not among the historically more common in the drainage. It is probable that they and other currently rare mussels were first propelled into decline by the depredations of the pearl button industry, which reduced their populations to such an extent that reproduction could no longer offset even natural mortality. During the intervening years, environmental degradation increased, contributing to their decline. In 1977, they were evidently below recruitment level in the survey area.

The most dramatic examples of the declining mussels, of course, are the two legally Endangered taxa that are recognized as valid species in this report: *Proptera* (often *Potamilus*) *capax*, Fat Pocketbook, and *Lampsilis higginsi*, Higgins' Eye. Another species of grave concern is *Cumberlandia monodonta*, Spectacle Case, which probably will soon receive nationally Threatened status. No traces of *P. capax* or of the rare *Leptodea leptodon* and *Simpsoniconcha ambigua* (Narrow Papershell and Salamander Mussel, respectively) were found. *Lampsilis higginsi* and *C. monodonta* were encountered alive at two Sites each. (Recovery programs for the latter two species would stand excellent chances for success.)

The field observations of mussel populations and their relationships to channel dredging by the Corps in the Upper Mississippi River basin indicate that this dredging has had only a minor impact on Endangered or other mussel species. This subject is summarized in the preceding Section. The losses in mussel populations observed in this study are apparently due to several factors in addition to the influence of Corps dredging. These factors include municipal, industrial, and agricultural wastes (the Twin Cities and the Minnesota and Des Moines Rivers are especially important sources); increased bedload, as from the Chippewa River; inadequate glochidial host opportunities (the classic victim is *Fusconaia ebena*, the Ebony Shell); scattered point sources, such as isolated power plant effluents; disease induced by microorganisms (Ellis, 1931b) and, perhaps, by unionicolid mites; dredging and disposal of riverbed material by the private sector; increased sedimentation caused by 9-Foot Channel Project impoundment; and, potentially as threatening to mussels as any of these other factors, the recent appearance in the study area of *Corbicula fluminea*, the Asiatic Clam.

The historical record and recent observations combine to provide materials of varying adequacy toward defining Critical Habitat for each of five ecologically (and, in two cases, legally) jeopardized species emphasized in this report. The Fat Pocketbook may linger in the backwaters, but its presence in the Upper Mississippi River in 1977 was in question. Higgin's Eye clearly favors mud and gravel bars. The others (see previous page) are characteristic of rocky areas, and the Spectacle Case, in particular, apparently can live in wingdams.

Several general observations and indications of needed research are supported by the present study. The need to avoid disturbance of rocky riverbed and the wingdams is evident, regardless of whether Corps dredging (or other activities by anyone) is undertaken for the purposes of either construction or channel maintenance. Similarly, and especially if recovery programs are undertaken, further research into glochidiosis will be necessary, because no larval hosts are known for three of these exceptionally jeopardized mussels. Another recommendation about needed research is implicit in pointing out that little or nothing taxon-specific is known about physiological responses of Upper Mississippi River mussels to toxic substances. Also, extension of the investigations by Marking and Bills (1977) into the impacts of sedimentation upon mussels is desirable. Increased knowledge in these areas would be of value to all mussels, not just the rare, Threatened, or Endangered species.

The preference of many mussel species for gravel streambeds has been demonstrated by many studies, including the Academy's field observations and the experimental study by

Kaskie (1971). Investigators are also becoming aware that mud (as opposed to silt, muck, or sludge), often not recognized as a favorable mussel substrate, forms prime habitat if it is sufficiently viscous. Therefore, future investigators should not depend exclusively on gravel bed and shore as investigative guides.

Water depth was found to be less limiting to mussel distribution than had been expected. Even in the navigation channel, mussels were found in abundance if the water was deep enough (commonly about 20 ft) to obviate maintenance dredging and to protect benthos from passing vessels.

Finally, an active educational effort is required to promote recognition of Endangered mussel species, in order to minimize their inadvertent loss to scientific, commercial, and other collectors.

APPENDICES

Appendix A

Mussel Classification and Nomenclature

This Appendix consists of three elements:

Exhibit 1.

Systematic List of Taxa

Exhibit 2.

Latin Synonyms

Exhibit 3.

Vernacular Names

Exhibit 1

Systematic List of Taxa

In the following phylogenetic list of known Upper Mississippi River fresh-water mussels, family-group and tribal taxa are those of Davis et al. (1978), and the suprafamilial classification is Newell's (1965).

Phylum MOLLUSCA
Class Bivalvia
Subclass Palaeoheterodonta
Order Unionoida
Family Unionidae
Subfamily Margaritiferinae
Cumberlandia monodonta (Say)
Subfamily Lampsilinae
Tribe Amblemini
Quadrula (Orthonymus) metanevra (Rafinesque)
Q. (Q.) quadrula Rafinesque
Q. (Bullata) nodulata (Rafinesque)
Q. (B.) pustulosa (Lea)
Tritogonia verrucosa (Rafinesque)
Cyclonaias tuberculata (Rafinesque)
Fusconaia flava (Rafinesque)
F. ebena (Lea)
Megalonaias gigantea (Barnes)
Amblema plicata (Say)
Tribe Elliptionini
Plethobasus cyphyus (Rafinesque)
Uniomerus tetralasmus (Say)
Pleurobema cordatum (Rafinesque)
Elliptio crassidens (Lamarck)
E. dilatata (Rafinesque)
Tribe Lampsilini
"Subtribe Mesogenae"
Obliquaria reflexa Rafinesque
"Subtribe Heterogenae"
Proptera alata (Say)
P. laevissima (Lea)
P. purpurata (Lamarck)
P. capax (Green)
Leptodea fragilis (Rafinesque)
L. leptodon (Rafinesque)
Ellipsaria lineolata (Rafinesque)
Truncilla truncata (Rafinesque)
T. donaciformis (Lea)
Obovaria olivaria (Rafinesque)
Actinonaias carinata (Barnes)
A. ellipsiformis (Conrad)

Ligumia recta (Lamarck)
L. subrostrata (Say)
Carunculina parva (Barnes)
Lampsilis teres (Rafinesque)
L. higginsi (Lea)
L. radiata siliquoidea (Barnes)
L. ovata ventricosa (Barnes)
Dysnomia triguetra (Rafinesque)
Subfamily Anodontinae
Arcidens confragosus (Say)
Lasmigona (Pterosyna) complanata (Barnes)
L. (L.) costata (Rafinesque)
L. (Platynaias) compressa (Lea)
Alasmidonta (Decurambis) marginata (Say)
A. (Pressodon) calceola (Lea)
Simpsoniconcha ambigua (Say)
Anodontoides ferussacianus (Lea)
Anodonta (Utterbackia) suborbiculata Say
A. (U.) imbecillis Say
A. (Pyganodon) grandis Say
Strophitus undulatus (Say)

Exhibit 2

Latin Synonyms

The lists below are restricted to the more common names of the last century or so, and emphasis is placed on those that have relevance to mussel populations of the Upper Mississippi River and its major tributaries. The lists do not constitute a monographic synonymy, so few references are given, but the especial value of Starrett's (1971) work must be acknowledged.

Many of these species-group taxa have in the past been classified in several different genera; these are given, usually as exhaustively as the Principle Investigator's knowledge permits. Species-group taxonomic synonyms are a bit less thoroughly treated because, there being more of them, a greater proportion is unimportant and because some relate only to populations outside the upper Mississippi basin.

Some of the species now placed in more or less edentate genera *(Anodonta, Strophitus, Alasmidonta, Leptodea)* were originally described in *Anodonta*; almost all others, in *Unio*. These initial designations are taken for granted in the following accounts. The elaborate genus-group concepts adopted by Rafinesque are somewhat exempted from this commentary.

Agreement of specific epithets with generic names according to the genders of the latter is rendered below solely with respect to the generally accepted genus of the day. *Amblema plicata* is a useful example. The relevant species-group synonyms are listed below with feminine suffices in each case. The specific epithet accepted for this report, *plicata* (feminine), was originally described as a *Unio* (masculine), as were the other relevant names. The commonly encountered synonym *costata*, for instance, is below considered feminine in agreement with *Amblema*, not masculine *(costatus)* in agreement with *Unio*.

Cumberlandia monodonta

The specific epithet has no common synonyms, but the generic name was often *Margaritana* or *Margaritifera* in early literature.

Quadrula metanevra

There are no common synonyms.

Quadrula quadrula

There are no common synonyms of *Quadrula,* but the specific epithet *lachrymosa* was often used for *quadrula* in early literature. Especially in the southern portion of its extensive range (e.g., in the Gulf drainage of Louisiana), this often highly variable species exhibits many morphs, most of which received names. Few, if any, other than *quadrula* itself have species-group validity, and none has much relevance to the Upper Mississippi River. Most of these nominal species were figured by Neel (1941).

Quadrula nodulata

The genus has no common synonyms, but the species used often to be called *pustulata.*

Quadrula pustulosa

Neither the epithet nor the genus has common synonyms.

Tritogonia verrucosa

This species was often referred to *Quadrula* in early literature. A common early synonym of the specific epithet is Barnes' name *tuberculata,* which has been confused with Rafinesque's *tuberculata,* which, in turn, is now applied to *Cyclonaias* (just below).

Cyclonaias tuberculata

Rotundaria was invalidated by Ortmann and Walker (1922), and to that work H.A. Pilsbry contributed *Cyclonaias* in its stead. In prior literature this species was often considered a *Quadrula.* The Upper Mississippi River morph is sometimes called *C. tuberculata granifera,* a subspecific concept of questionable validity. Confusion about the epithet *tuberculata* is discussed under *Tritogonia verrucosa* (just above).

Fusconaia flava

At one time members of *Fusconaia* were sometimes placed in *Quadrula.* The nominal species *F. undata* (Lea) and *F. flava* are conspecific (D.H. Stansbery *in* Starrett, 1971); the latter specific name has priority. These are the only two relevant epithets that retain much currency in the upper Mississippi

basin, but there are several names that were regularly used instead of one or both of these: *trigona, rubiginosa,* and perhaps *solida.*

Fusconaia ebena

The species has been referred to *Quadrula,* and the epithet has no common synonyms.

Megalonaias gigantea

This species was regularly considered a *Quadrula* in early literature. Common synonyms of the epithet are *multiplicata, heros,* and *nervosa.*

Amblema plicata

Crenodonta is still occasionally, but wrongly, used instead of *Amblema.* In this report all Threeridge in the Upper Mississippi River are interpreted as belonging to a single, variable species, for which *plicata* is the earliest name. Other epithets still in use for various Mississippi basin morphs include *peruviana, costata, undulata,* and *rariplicata.* The correct number of biological species of *Amblema* remains in doubt. Also uncertain are the relationships among *A. plicata* and the Gulf drainage nominal species *A. perplicata* (Conrad) and *A. neisleri* (Lea).

Plethobasus cyphyus

The species used regularly to be referred to *Pleurobema.* A common early synonym of the epithet is *aesopus.*

Uniomerus tetralasmus

The correct number of biological species of *Uniomerus* has always been moot, and modern workers agree no more than did the early ones. Johnson (1970), for example, considered this genus monotypic, whereas Morrison (1977) claimed several species. Among the more common relevant specific epithets are *declivis, obesus, exculτus, parallelus, symmetricus, camptodon, manubius,* and *columbensis.* Only *tetralasmus* (sometimes *sayi*) ordinarily occurs in literature about the Mississippi basin. Most of these at least nominal species have been referred to

Elliptio at various times.

Pleurobema cordatum

This animal belongs to a taxonomically perplexing group of morphs. Recent practice is followed here by using the specific epithet *cordatum* for the Upper Mississippi River representative of the complex. Commonly used names that are probably synonyms of the epithet include *coccineum, obliquum, pyramidatum,* and *catillum.*

Elliptio crassidens

There are no common synonyms of this taxon's Upper Mississippi River population.

Elliptio dilatata

The specific epithet is regularly misspelled as *dilatatus*, but *Elliptio* is feminine (H.B. Baker, 1964b), so the correct spelling is *dilatata.* The only common synonym relevant to the Upper Mississippi River is *gibbosa.* This species has been misidentified with male *Ligumia,* especially *L. recta.*

Obliquaria reflexa

The generic name has no common synonyms, and the only one for the specific epithet is *cornuta.*

Proptera alata

There are no common synonyms of the specific epithet, but this species has often been referred to *Lampsilis.* Some authorities accept *Potamilus* as preferable to *Proptera.*

Proptera laevissima

The specific epithet has no common synonyms. The species has often been referred to *Lampsilis, Leptodea,* or *Potamilus.*

Proptera purpurata

This species has been placed in *Lampsilis* and *Potamilus.* Its epithet has no common synonyms.

Proptera capax

There are no common synonyms for the specific epithet. The species has been considered a *Lampsilis* or *Potamilus*.

Leptodea fragilis

The only common synonym of the specific epithet is *gracilis*. The species has been referred to *Lampsilis* and to *Paraptera*, an objective junior synonym of *Leptodea*.

Leptodea leptodon

There are no common synonyms of the specific epithet. The species has sometimes been interpreted as a *Lampsilis*.

Ellipsaria lineolata

H.B. Baker (1964a) showed that *Ellipsaria* has priority over the far more familiar *Plagiola* of recent tradition. The specific epithet has only one common synonym, *securis*.

Truncilla truncata

This species has been ascribed to *Amygdalonaias* (sometimes misspelled *Amygdalonajas*) and *Plagiola*. The only common synonym of the specific epithet is *elegans*.

Truncilla donaciformis

The specific epithet *zigzag* is the only common synonym for *donaciformis*. For further relevant remarks, see *Truncilla truncata* (above).

Obovaria olivaria

This species has occasionally been considered a *Lampsilis*. The specific epithet's only common synonym is *ellipsis*.

Actinonaias carinata

This report treats this animal as a species taxonomically undissected by subspecific concepts. Thorough taxonomic analysis of this species is topically and perhaps geographically

extralimital to the present document. However, it must be realized that some authorities recognize subspecies *Actinonaias c. carinata* and *A. c. gibba*. The latter at least nominal subspecies presumably does not occur in the Upper Mississippi River.

Actinonaias carinata has been referred to *Nephronaias* (often misspelled *Nephronajas*) and *Lampsilis*. The specific epithet has only a single common synonym, *ligamentina*, which, believe some authorities, is the name of precedence.

Actinonaias ellipsiformis

The species has been known by the epithet *spatulata* and referred to *Lampsilis*, *Nephronaias* (sometimes misspelled *Nephronajas*), *Eurynia*, *Micromya* (preoccupied senior synonym of *Villosa*), and *Ligumia*. Its correct generic position remains in doubt.

Ligumia recta

Lampsilis and *Eurynia* have often been used as the generic name of this species. The only common species-group synonym of *recta* is *latissima*, which is commonly employed in the subspecific trinomial *Ligumia recta latissima*, as opposed to a nominal subspecies *L. r. recta*. To attempt a validation of either combination is not a purpose of this report, although *latissima* probably has no biological validity.

Ligumia subrostrata

The specific epithet has no common synonyms in the Upper Mississippi River. (Conrad's name *mississippiensis* is a rare synonym). The species has been ascribed to *Lampsilis* and perhaps to *Eurynia*.

Carunculina parva

This animal belongs to a taxonomically challenging genus, the number of whose biological species and the discriminants among them are not understood. Opinions range from the probably exorbitant (e.g., Call, 1896) through the definitely simplistic (e.g., Johnson, 1970).

On the other hand, the earliest recognized member of *Carunculina* appears to be *C. parva* (a Barnes species of 1823),

and the original material, like so much of Barnes', probably came from the upper Mississippi basin. For these reasons, it is reasonable to regard Upper Mississippi River *Carunculina* as true (and presumably typical) *C. parva*.

The epithet *parva* has no common synonyms in the Upper Mississippi River. The species has been placed alternatively in *Lampsilis*, *Eurynia*, and *Toxolasma*, a recently resurrected and allegedly objective synonym of *Carunculina*.

Lampsilis teres

The nominal species *Lampsilis fallaciosa* 'Smith' Simpson, the Slough Sandshell (sometimes considered a subspecies, *L. teres fallaciosa*, of *L. t. teres*), is conceded no taxonomic validity in this report and is thus interpreted as a synonymous morph of *L. teres*, the Yellow Sandshell. The only relevant further synonym is the epithet *anodontoides*, regularly used instead of *teres* prior to Johnson (1972).

Lampsilis higginsi

There is offered here no attempt to resolve the controversial relationships among the nominal species *L. higginsi*, *L. orbiculata* (Hildreth), *L. abrupta* (Say). These taxa are considered synonymous for the purposes of this report, and there is no further commonly encountered synonymy.

Lampsilis radiata siliquoidea

Morphological investigations conducted during this survey have demonstrated that the Fat Mucket of the Upper Mississippi River is definitely a part of the *Lampsilis radiata* complex of the Atlantic drainage. There is little doubt that, for example, the representative population in Lake Waccamaw, southeastern North Carolina, deserves subspecific recognition (see Fuller, 1977b). Thus, taxonomic subdivision of the venerable concept "*Lampsilis radiata*" is a defensible proposition. Accordingly, the Principal Investigator accepts the Fat Mucket of the upper Mississippi basin as a conspecific subspecies in the group of *L. r. radiata*. The only important aspect of synonymy or other nomenclatural difficulty is the opposition of the species-group epithets *siliquoidea* and *luteola*. The practice here reflects acceptance of Clarke's (1973) reasons for favoring the former. However much perchance, previous authors (e. g., Murray and Leonard, 1962) appear to have been correct in calling the Fat Mucket *L. r. siliquoidea*.

Lampsilis ovata ventricosa

This account reflects Cvancara's (1963) opinion that the nominal species *Lampsilis ovata* and *L. ventricosa* form an essentially northwest-southwest cline. It follows that the two may reasonably be regarded as conspecific subspecies. Because *ovata* is the earlier name, the combinations are *L. o. ovata* and *L. o. ventricosa*. There are no other important relevant problems in synonymy that involve the latter in the Upper Mississippi River.

Dysnomia triquetra

This species has no common synonymous epithets. This and other *Dysnomia* were wrongly placed in *Truncilla* for many years. There have been recent attempts to revive *Epioblasma* in place of *Dysnomia*.

Arcidens confragosus

The gender of *Arcidens* is male, but the epithet is sometimes spelled *confragosa*. This species has been referred to *Alasmidonta*.

Lasmigona complanata

The specific epithet has no common synonyms. The species has been placed in *Alasmidonta*, *Margaritana* (an invalid name), *Symphynota* (another), and *Lasmigon* (a third).

Lasmigona costata

The epithet *rugosa* used to occur occasionally instead of *costata*. See *Lasmigona complanata* (above) for alternative generic placements.

Lasmigona compressa

There are no common synonyms of Upper Mississippi River populations of this species. See *Lasmigona complanata* (above) for alternative generic placements.

Alasmidonta marginata

The species has been referred to the invalid *Margaritana*, and its subgenus, *Decurambis*, is sometimes given generic rank,

in which case it becomes a functional synonym of *Alasmidonta*. The epithet, *marginata*, has no common synonyms.

Alasmidonta calceola

This species has been grouped in the invalid *Margaritana*. The epithet has no common synonyms.

Simpsoniconcha ambigua

The synonymous epithet *hildrethiana* occurs in older literature. The species has been ascribed to *Hemilastena*, *Alasmidonta*, *Margaritana*, *Margarita*, *Margoron*, *Strophitus*, and *Baphia*.

Anodontoides ferussacianus

This species was ascribed to *Anodonta* in the very early literature. There are no common synonymous specific epithets.

Anodonta suborbiculata

There are no common synonyms of any kind. See *Anodonta imbecillis* (below).

Anodonta imbecillis

There are no common synonyms of the specific epithet, but occasionally an old controversy is resurrected over the name *ohiensis*, an alleged alternative (see Ortmann and Walker, 1922). There are two genus-group names, *Utterbackia* and *Utterbackiana*, that have been used instead of *Anodonta* in the case of this species; also, the invalid *Anodon* used to receive this and other *Anodonta*. There are two spellings of the epithet, *imbecilis* and *imbecillis*; each is correct Latin, but the latter is the original and must be used.

Anodonta grandis

Two specific epithets, *grandis* and *corpulenta*, are common and relevant to this taxonomically controversial animal. There are three common opinions: recognize (1) two species, *Anodonta grandis* and *A. corpulenta*; (2) two conspecific subspecies, *A. g. grandis* and *A. g. corpulenta*; or (3) a single species, *A. grandis*. The third course is taken here, but the matter is unresolved. See *A. imbecillis* (above).

Strophitus undulatus

This species has been placed in *Anodonta* and the invalid *Anodon*, but neither disposition is common today. The correct number of biological species in *Strophitus* is moot. The competing specific epithets *undulatus*, *edentulus*, and *rugosus* are in use, chiefly according to the geographic locations of the material in question. Earliest of the three is *undulatus*, which is employed here on the debatable grounds that the genus is monotypic in the northern tier of states. The Gulf drainage taxon *S. subvexus* (Conrad), for example, may be valid.

Exhibit 3

Vernacular Names

The exact source of any vernacular expression is nearly or quite impossible to know. Moreover, such expressions vary geographically and often profoundly. Consequently, no attempt has been made to cite original sources for any of the common names on the list below. However, it is possible to provide citations of important works in which such names have been encountered; for the purposes of this report, these include Coker (1915b, 1919) Sterki (1910), Carlander (1954), Murray and Leonard (1962), Parmalee (1967), Shimek (1921), and Starrett (1971).

The names listed below are restricted to the more common vernaculars. Minor variations (e.g., hyphenations, ellisions, colloquial misspellings, trivially qualified versions, etc.) are ignored. The existence of vernacular names that are ethnic and/or racial slurs is acknowledged, but none is listed. Novel common names were coined when none was extant, and certain traditional ones have been modified in order to reduce ambiguity and increase consistency.

The advantage of common names over those in sometimes intimidating Latin is obvious provided that the vernacular names are wrought according to sound principles and are standardized (i.e., nearly or quite universally accepted). This document offers no such opportunity, but common names have been adopted in a reasoned way for use in the report. The precepts of Bailey et al. (1970) for fish names have been essentially followed, although, for the sake of clarity and emphasis, all elements of a vernacular name are capitalized here.

Each name chosen for common use in this report is indicated by an asterisk (*) below.

Cumberlandia monodonta	*Spectacle Case Donkey's Ear Ass' Ear
Quadrula metanevra	*Monkeyface
Q. quadrula	*Mapleleaf Stranger
Q. nodulata	*Wartyback White Wartyback Pimpleback

Q. pustulosa	*Pimpleback White Wartyback Warty Pigtoe
Tritogonia verrucosa	*Buckhorn Deerhorn Pistol Grip
Cyclonaias tuberculata	*Purple Pimpleback Purple Wartyback
Fusconaia flava	*Pigtoe
F. ebena	*Ebony Shell Black Shell
Megalonaias gigantea	*Washboard
Amblema plicata	*Threeridge Threeridge Washboard Washboard Blue Point
Plethobasus cyphyus	*Bullhead Pigtoe Sheepnose
Uniomerus tetralasmus	*Pondhorn
Pleurobema cordatum	*Ohio River Pigtoe Pigtoe
Elliptio crassidens	*Elephant Ear
E. dilatata	*Spike Black Sandclam Sandclam Ladyfinger
Obliquaria reflexa	*Threehorn Three-Horned Warty Back
Proptera alata	*Pink Heelsplitter Pancake Razorback Rudderback Hatchetback Hackleback
P. laevissima	*Pink Papershell Papershell

P. purpurata	*Purple Pocketbook Purply Bluefer
P. capax	*Fat Pocketbook Pocketbook
Leptodea fragilis	*Fragile Papershell Papershell
L. leptodon	*Narrow Papershell
Ellipsaria lineolata	*Butterfly
Truncilla truncata	*Deertoe
T. donaciformis	*Fawnfoot Fawn's Foot Smaller Deertoe
Obovaria olivaria	*Hickorynut Glassback Eggshell Long Solid
Actinonaias carinata	*Mucket Mouket Mougat
A. ellipsiformis	*Ellipse
Ligumia recta	*Black Sandshell Black Sandclam Sandclam
L. subrostrata	*Western Pondmussel Pond Mussel
Carunculina parva	*Lilliput Lilliput Shell Small Papershell
Lampsilis teres	*Yellow Sandshell Slough Sandshell Ladyfinger Banana Shell
L. higginsi	*Higgins' Eye Higgins Eye Higgin's [*sic*] Eye Higgin's Sandshell Mucket

L. radiata siliquoidea	*Fat Mucket Lake Pepin Mucket
L. ovata ventricosa	*Pocketbook Grandma
Dysnomia triquetra	*Snuffbox
Arcidens confragosus	*Rockshell Rock Pocketbook Bastard Bastard Shell
Lasmigona complanata	*White Heelsplitter Pancake Elephant Ear Razorback Rudderback Hatchetback
L. costata	*Fluted Shell
L. compressa	*Creek Heelsplitter
Alasmidonta marginata	*Elktoe
A. calceola	*Slippershell
Simpsoniconcha ambigua	*Salamander Mussel
Anodontoides ferussacianus	*Cylinder Cylindrical Paper Shell
Anodonta suborbiculata	*Flat Floater Heelsplitter
Anodonta imbecillis	*Paper Floater Paper Pond Shell Small Papershell
Anodonta grandis	*Giant Floater Larger Floater. Floater Slop Bucket
Strophitus undulatus	*Strange Floater

Appendix B

1977 Collection Data

Sites and Samples (Exhibits 4 - 46)

The field personnel indicated by their initials in the Exhibits may be identified according to the following legend.

EA	--	Edward Ambrogio
DJB	--	Daniel J. Bereza
RFB	--	Richard F. Berry
FWB	--	Frederick W. Breitenbach
MAC	--	Michael A. Cockerill
FWC	--	Francis W. Collins
BLD	--	Billy L. Davis
TMF	--	Thomas M. Freitag
SLHF	--	Samuel L. H. Fuller
RCH	--	Robert C. Halvorsen
RJJ	--	Richard J. Jones
JEM	--	Joy E. Mathisen
JLP	--	James L. Peterson
LLP	--	Larry L. Protsman
DLR	--	Donald L. Rudd
RLT	--	Roger L. Thomas
SJT	--	Sandra J. Thomas
RJW	--	Robert J. Whiting

The area of the riverbed examined at a given Site is an approximation that was worked out in the following way. Field observations had indicated that the average length of a brail drag was about 500 feet. The length of an Academy brail is 10 feet. Therefore, the area of streambed covered by a single brail run was about 5,000 square feet. Multiplication of this product by the total number of brail runs gives the total area brailed at the Site.

Numbers of brail runs at certain Sites surveyed early in the field work are marked by an asterisk (*). These figures are minima only, because the Principal Investigator had not recognized the usefulness of accurately recording totals of negative runs.

The reader is advised to "See Exhibit 'X'" (in Appendix C) for relevant mussel data in the case of a Site where the Academy established no mussel records of any kind, but for whose Pool there are historical records. The existence of no relevant records is indicated by "Mussel data: none". If there exist Site-specific records, reference is made to the appropriate Exhibit.

No water depths are provided, because changing river stages meant that Sites and habitats could not meaningfully be compared in terms of depth.

Exhibit 4

Below Cargill, Petersons Bar,
Above Route I-35W Bridge

Mussel data: See Exhibit 49

Pool(s): not applicable

Date(s): 5 August 1977

Locality: Minnesota River, RM 10.5 - 12.9, Bloomington, Hennepin County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	0
Brail runs:	negative:	15*
	total:	15*

Sampling area (square feet): 75,000

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* Minimum

Exhibit 5

Hudson RR Bridge

Mussel data: Exhibit 52

Pool(s): not applicable

Date(s): 8-13 August, 14-15 September 1977

Locality: St. Croix River, RM 15.9 - 18.1, Hudson, St. Croix County, Wisconsin

Collector(s): EA, DJB, RFB, SLHF, RCH, SDS, RLT, RJW

Collecting technique(s): brailing, pollywogging, diving

Brail runs:

positive:	43
negative:	54
total:	97

Sampling area (square feet): 485,000

Exhibit 6

Below SOO Line RR Bridge

Mussel data: none

Pool(s): Upper Saint Anthony Falls (USAF)

Date(s): 2 August 1977

Locality: Mississippi River, RM 855.8 - 857.6, Minneapolis, Hennepin County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	0
Brail runs:	negative:	10*
	total:	10*

Sampling area (square feet): 50,000

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* Minimum

Exhibit 7

Above and Below Broadway Avenue and Plymouth Avenue Bridges

Mussel data: none

Pool(s): Upper St. Anthony Falls (USAF)

Date(s): 2 August 1977

Locality: Mississippi River, RM 853.8 - 855.7, Minneapolis, Hennepin County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	0
Brail runs:	negative:	6
	total:	6

Sampling area (square feet): 30,000

Exhibit 8

Above and Below Lake Street Bridge

Mussel data: See Exhibit 36

Pool(s): 1

Date(s): 1 August 1977

Locality: Mississippi River, RM 849.1 - 850.6, St. Paul, Ramsey County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

Brail runs:

positive:	0
negative:	10
total:	10

Sampling area (square feet): 50,000

Exhibit 9

Below St. Paul Daymark 849.1

Mussel data: See Exhibit 56

Pool(s): 1

Date(s): 1 August 1977

Locality: Mississippi River, RM 847.8 - 849.1, St. Paul, Ramsey County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	0
Brail runs:	negative:	5
	total:	5

Sampling area (square feet): 25,000

Exhibit 10

Locks and Dam 1 Upper Approach Construction

Mussel data: Exhibit 58

Pool(s): 1 and 2

Date(s): 2-3 August 1977

Locality: Mississippi River, RM 846.2-847.8, St. Paul, Ramsey County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	6
Brail runs:	negative:	14
	total:	20

Sampling area (square feet): 100,000

Exhibit 11

Above and Below Smith Avenue ("High") Bridge

Mussel data: See Exhibit 57

Pool(s): 2

Date(s): 31 July 1977

Locality: Mississippi River, RM 839.2 - 840.6, St. Paul, Ramsey County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	0
Brail runs:	negative:	6
	total:	6

Sampling area (square feet): 30,000

Exhibit 12

Robinsons Rocks

Mussel data: See Exhibit 57

Pool(s): 2

Date(s): 28 July 1977

Locality: Mississippi River, RM 825.0 - 826.6, about 3 miles S St. Paul Park, Washington County, Minnesota

Collector(s): EA, RFB, SLHF, RLT, RJW

Collecting technique(s): brailing

Brail runs: positive: 0
negative: 12
total: 12

Sampling area (square feet): 60,000

Exhibit 13

Nininger

Mussel data: See Exhibit 57

Pool(s): 2

Date(s): 29 July 1977

Locality: Mississippi River, RM 816.6 - 818.7, about 3 miles NE Hastings, Dakota County, Minnesota

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

Brail runs:

positive: 0

negative: 14

total: 14

Sampling area (square feet): 70,000

Exhibit 14

Lake City Small Boat Harbor Entrance

Mussel data: Exhibit 61

Pool(s): 4

Date(s): 18 September 1977

Locality: Mississippi River, RM 772.5 - 772.8, Lake City, Wabasha County, Minnesota

Collector(s): EA, DJB, RLT

Collecting technique(s): brailing

	positive:	3
Brail runs:	negative:	6
	total:	9

Sampling area (square feet): 45,000

Exhibit 15

Reads Landing

Mussel data: Exhibit 62

Pool(s): 4

Date(s): 21-22, 29 September 1977

Locality: Mississippi River, RM 760.6 - 763.8, Reads Landing, Wabasha County, Minnesota

Collector(s): EA, DJB, SLHF, RCH, RLT

Collecting technique(s): brailling, pollywogging

	positive:	6
Brail runs:	negative:	67
	total:	73

Sampling area (square feet): 365,000

Exhibit 16

Teepeeota Point

Mussel data: Exhibit 63

Pool(s): 4

Date(s): 20 September 1977

Locality: Mississippi River, RM 757.0 - 758.4, about 2 miles SE Wabasha, Wabasha County, Minnesota

Collector(s): EA, DJB, RCH, RLT

Collecting technique(s): brailing

Brail runs:
positive: 13
negative: 38
total: 51

Sampling area (square feet): 255,000

Exhibit 17

Grand Encampment

Mussel data: Exhibit 64

Pool(s): 4

Date(s): 19 September 1977

Locality: Mississippi River, RM 754.6 - 757.0, about 3.5 miles SE Wabasha, Wabasha County, Minnesota

Collector(s): EA, DJB, SLHF, RCH, RLT

Collecting technique(s): brailing

	positive:	9
Brail runs:	negative:	31
	total:	40

Sampling area (square feet): 200,000

Exhibit 18

West Newton

Mussel data: Exhibit 66

Pool(s): 5

Date(s): 23-26 September 1977

Locality: Mississippi River, RM 746.6 - 743.3, about 3.5 miles SSE Alma, Buffalo County, Wisconsin

Collector(s): EA, DJB, RCH, RLT

Collecting technique(s): brailing

	positive:	67
Brail runs:	negative:	22
	total:	89

Sampling area (square feet): 445,000

Exhibit 19

Weaver Bottom Complex

Mussel data: Exhibit 67

Pool(s): 5

Date(s): 25-28 September 1977

Locality: Mississippi River, RM 741.0 - 746.6, Minneiska, Winona County, Minnesota

Collector(s): EA, DJB, RLT

Collecting technique(s): brailing

Brail runs: positive: 64
negative: 48
total: 112

Sampling area (square feet): 560,000

Exhibit 20

Locks and Dam 5 Culvert Construction

Mussel data: Exhibit 68

Pool(s): 5 and 5A

Date(s): 26, 28 September 1977

Locality: Mississippi River, RM 740.4 - 740.6, about 3 miles SE Buffalo, Buffalo County, Wisconsin

Collector(s): DJB

Collecting technique(s): pollywogging, scraping

	positive:	0
Brail runs:	negative:	0
	total:	0

Sampling area (square feet): incalculable

Exhibit 21

Above Brownsville

Mussel data: Exhibit 73

Pool(s): 8

Date(s): 2-3 October 1977

Locality: Mississippi River, RM 689.8 - 691.2, about 2 miles N Brownsville, Houston County, Minnesota

Collector(s): EA, RLT, SJT

Collecting technique(s): brailing

	positive:	34
Brail runs:	negative:	24
	total:	58

Sampling area (square feet): 290,000

Exhibit 22

Brownsville

Mussel data: Exhibit 74

Pool(s): 8

Date(s): 15 August 1977

Locality: Mississippi River, RM 685.4 - 689.8, Brownsville, Houston County, Minnesota

Collector(s): EA, SLHF, RLT, RJW

Collecting technique(s): brailing

	positive:	29
Brail runs:	negative:	9
	total:	38

Sampling area (square feet): 190,000

Exhibit 23

Above Indian Camp Light

Mussel data: Exhibit 76

Pool(s): 9

Date(s): 9-10 October 1977

Locality: Mississippi River, RM 666.0 - 667.0, Desoto, Vernon County, Wisconsin

Collector(s): EA, SLHF, RLT, SJT

Collecting technique(s): brailing

Brail runs:	positive:	13
	negative:	23
	total:	36

Sampling area (square feet): 180,000

Exhibit 24

Indian Camp Light

Mussel data: Exhibit 77

Pool(s): 9

Date(s): 10-12 October 1977

Locality: Mississippi River, RM 664.9 - 666.0, about 2 miles SW Desoto, Vernon County, Wisconsin

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

	positive:	9
Brail runs:	negative:	21
	total:	30

Sampling area (square feet): 150,000

Exhibit 25

Lansing Upper Light

Mussel data: Exhibit 78

Pool(s): 9

Date(s): 11-12 October 1977

Locality: Mississippi River, RM 662.4 - 664.9, Lansing, Allamakee County, Iowa

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	18
Brail runs:	negative:	36
	total:	54

Sampling area (square feet): 270,000

Exhibit 26

Hay Point Bank Repair

Mussel data: Exhibit 80

Pool(s): 10

Date(s): 5-6 October 1977

Locality: Mississippi River, RM 644.8 - 646.8, about 5 miles SW Lynxville, Crawford County, Wisconsin

Collector(s): EA, SLHF, JLP, RLT, SJT

Collecting technique(s): brailing

	positive:	44
Brail runs:	negative:	31
	total:	75

Sampling area (square feet): 375,000

Exhibit 27

Island 189

Mussel data: Exhibit 83

Pool(s): 11

Date(s): 17 October 1977

Locality: Mississippi River, RM 609.1 - 610.7, about 5 miles SE Guttenberg, Clayton County, Iowa

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	9
Brail runs:	negative:	24
	total:	33

Sampling area (square feet): 165,000

Exhibit 28

Hurricane Chute

Mussel data: Exhibit 84

Pool(s): 11

Date(s): 19-20 October 1977

Locality: Mississippi River, RM 597.6 - 599.4, about 1 mile E Waupeton, Dubuque County, Iowa

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing, scraping

	positive:	27
Brail runs:	negative:	21
	total:	48

Sampling area (square feet): 240,000

Exhibit 29

Savanna

Mussel data: Exhibit 87

Pool(s): 13

Date(s): 18-19 August 1977

Locality: Mississippi River, RM 537.2 - 539.1, Savanna,
Carroll County, Illinois

Collector(s): EA, SLHF, RJJ, LLP, RLT

Collecting technique(s): brailing

	positive:	20
Brail runs:	**negative:**	22
	total:	42

Sampling area (square feet): 210,000

Exhibit 30

Sabula

Mussel data: Exhibit 88

Pool(s): 13

Date(s): 22-23 August 1977

Locality: Mississippi River, RM 532.9 - 534.2, Sabula,
Jackson County, Iowa

Collector(s): EA, SLHF, DLR, RLT

Collecting technique(s): brailing

	positive:	34
Brail runs:	**negative:**	21
	total:	55

Sampling area (square feet): 275,000

Exhibit 31

Dark Slough

Mussel data: Exhibit 89

Pool(s): 13

Date(s): 22 October 1977

Locality: Mississippi River, RM 530.0 - 531.3, about 5 miles S Sabula, Jackson County, Iowa

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	8
Brail runs:	negative:	14
	total:	22

Sampling area (square feet): 110,000

Exhibit 32

Locks and Dam 14 Upper Approach

Mussel data: Exhibits 91 and 93

Pool(s): 14 and 15

Date(s): 24 October 1977

Locality: Mississippi River, RM 492.5 - 494.0, about 5 miles SW LeClaire, Scott County, Iowa

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	12
Brail runs:	negative:	19
	total:	31

Sampling area (square feet): 155,000

Exhibit 33

Centennial Bridge

Mussel data: Exhibit 95

Pool(s): 16

Date(s): 25-26 August 1977

Locality: Mississippi River, RM 430.7 - 432.0, Rock Island, Rock Island County, Illinois

Collector(s): EA, TMF, SLHF, DLR, RLT

Collecting technique(s): brailing, scraping

	positive:	27
Brail runs:	**negative:**	18
	total:	45

Sampling area (square feet): 225,000

Exhibit 34

Bass Island

Mussel data: Exhibit 97

Pool(s): 17

Date(s): 27 October 1977

Locality: Mississippi River, RM 446.6 - 448.2, about 7 miles S Muscatine, Muscatine County, Iowa

Collector(s): EA, RLT

Collecting technique(s): brailing, scraping

	positive:	27
Brail runs:	negative:	14
	total:	41

Sampling area (square feet): 205,000

Exhibit 35

New Boston Upper Light

Mussel data: Exhibit 99

Pool(s): 18

Date(s): 28 October 1977

Locality: Mississippi River, RM 432.5 - 434.1, New Boston,
Mercer County, Illinois

Collector(s): EA, SLHF, RLT

Collecting technique(s): brailing

Brail runs:	positive:	11
	negative:	16
	total:	27

Sampling area (square feet): 135,000

Exhibit 36

Edwards River

Mussel data: Exhibit 100

Pool(s): 18

Date(s): 23 August 1977

Locality: Mississippi River, RM 430.1 - 432.2, about 2 miles SSE New Boston, Mercer County, Illinois

Collector(s): SLHF, DLR, RLT, SJT

Collecting technique(s): brailing

	positive:	24
Brail runs:	negative:	9
	total:	33

Sampling area (square feet): 165,000

Exhibit 37

Craigel Island

Mussel data: Exhibit 102

Pool(s): 19

Date(s): 30-31 October, 1 November 1977

Locality: Mississippi River, RM 398.4 - 400.3, Burlington, Des Moines County, Iowa

Collector(s): SLHF, RLT

Collecting technique(s): brailing

	positive:	38
Brail runs:	negative:	21
	total:	59

Sampling area (square feet): 295,000

Exhibit 38

The "Green Bay" Sites:
Turkey, Thompson, and Dallas Islands;
Pontoosuc; and Hog Island

Mussel data: Exhibit 103 - 108

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 386.5 - 395.0, Henderson and Hancock Counties, Illinois

Collector(s): EA, DJB, FVB, MAC, FMC, BLD, SLHF, RJJ, JEM, LLP, DLR, RLT, SJT

Collecting technique(s): brailing, pollywogging, scraping dredging

	positive:	199
Brail runs:	negative:	56
	total:	255

Sampling area (square feet): 1,275,000

Exhibit 39

Turkey Island

Mussel data: Exhibit 104

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 393.7 - 395.0, about 2 miles W Lomax, Henderson County, Illinois

Collector(s): EA, DJB, SLHF, RJJ, JEM, LLP, DLR, RLT, SJT

Collecting technique(s): brailing, pollywogging, scraping dredging

Brail runs:

positive:	23
negative:	14
total:	37

Sampling area (square feet): 185,000

Exhibit 40

Thompson Island

Mussel data: Exhibit 105

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 390.0 - 392.7, about 1 mile N Dallas City, Hancock County, Illinois

Collector(s): EA, DJB, SLHF, RJJ, JEM, LLP, DLR, BLT, SJT

Collecting technique(s): brailing, dredging

	positive:	42
Brail runs:	**negative:**	10
	total:	52

Sampling area (square feet): 260,000

Exhibit 41

Dallas Island

Mussel data: Exhibit 106

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 389.0 - 390.3, opposite Dallas City, Hancock County, Illinois

Collector(s): EA, DJB, FWB, MAC, FWC, BLD, SIHF, RJJ, JEM, LLP, DLR, RLT, SJT

Collecting technique(s): brailing, dredging

	positive:	69
Brail runs:	negative:	6
	total:	75

Sampling area (square feet): 375,000

Exhibit 42

Pontoosuc

Mussel data: Exhibit 107

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 387.8 - 388.6, Pontoosuc, Hancock County, Illinois

Collector(s): EA, DJB, SLHF, RJJ, JEM, LLP, DLR, RLT, SJT

Collecting technique(s): brailing

	positive:	42
Brail runs:	negative:	9
	total:	51

Sampling area (square feet): 255,000

Exhibit 43

Hog Island

Mussel data: Exhibit 108

Pool(s): 19

Date(s): 30-31 August, 1-7 September 1977

Locality: Mississippi River, RM 386.5 - 387.8, about 1 mile W Pontoosuc, Hancock County, Illinois

Collector(s): EA, DJB, SLHF, RJJ, JEM, LLP, DLR, RLT, SJT

Collecting technique(s): brailing, pollywogging, scraping dredging

Brail runs:
- positive: 23
- negative: 17
- total: 40

Sampling area (square feet): 200,000

Exhibit 44

Fox Island

Mussel data: Exhibit 110

Pool(s): 20

Date(s): 3-4 November 1977

Locality: Mississippi River, RM 353.8 - 355.9, about - miles SSW Alexandria, Clark County, Missouri

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	11
Brail runs:	negative:	34
	total:	45

Sampling area (square feet): 225,000

Exhibit 45

Buzzard Island

Mussel data: Exhibit 111

Pool(s): 20

Date(s): 5-6 November 1977

Locality: Mississippi River, RM 347.9 - 349.7, about 7 miles N Canton, Lewis County, Missouri

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	14
Brail runs:	**negative:**	40
	total:	54

Sampling area (square feet): 270,000

Exhibit 46

Howards

Mussel data: Exhibit 113

Pool(s): 21

Date(s): 6-7 November 1977

Locality: Mississippi River, RM 338.5 - 340.3, about 3 miles

S Canton, Lewis County, Missouri

Collector(s): EA, RLT

Collecting technique(s): brailing

	positive:	17
Brail runs:	negative:	27
	total:	44

Sampling area (square feet): 220,000

Mussel Bed Maps

Exhibits 47 and 48

Approximate outlines of known, currently "active" (i.e., living) mussel beds that the Academy sampled in 1977 by brailing are represented by dotted lines, attention to which is drawn by solid arrows. Diving was not employed in order to verify the limits and densities of beds. Consequently, neither size nor age-class structure is known for any of them. The comparative representations of these mussels can be approximately inferred from data in the corresponding Exhibits in Appendix C.

For the purposes of this report, mussel "beds" (as opposed, for example, to "seams") are defined as those few populations that, in the Principal Investigator's judgment, were significantly more species- and individual-rich than all other populations, as judged by brailing results. This subjective criterion is used in the absence of a preferable alternative.

Approximate locations (in Exhibit 48 only) of the Academy's 1977 living samples of Spectacle Case, *Cumberlandia monodonta*, are represented by solid squares.

The bed off Dallas City (Exhibit 48) is part of the Thompson Island Site.

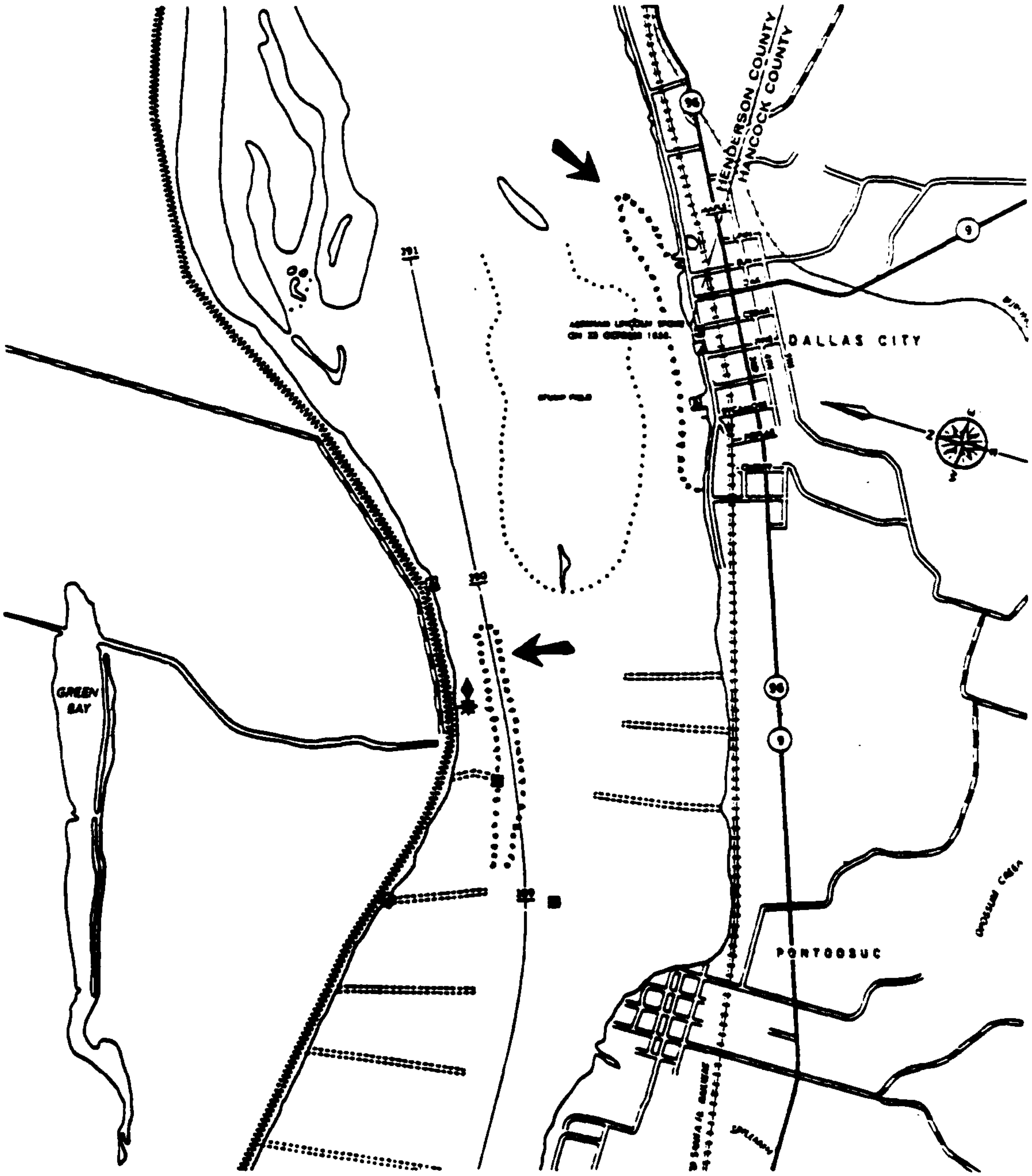
Also in Exhibit 48 is a representation (USACE, 1975) of the landlocked water body Green Bay (of Iowa, not Wisconsin), for which the Green Bay Drainage and Levee District and the "Green Bay Sites" of this report are named.

Exhibit 47

Hay Point Bank Repair

Exhibit 48

Dallas Island and Pontoosuc



Appendix C

Past and Present Mussel Presence/Absence and Proportional Data

Exhibits 49 -119

The legend below explains the symbolism used in the following Exhibits.

LEGEND

An "x" indicates presence; no symbol, absence. An "x" without a superscript indicates Academy 1977 field collecting data. An "x" with a superscript indicates the presence of the given taxon within the given period of time; the superscript (see Superscripts, below) refers to the (non-Academy) source of the record.

The column to the left of the names of taxa consists of records of living mussels collected in 1977. (The identity of the source is indicated by the presence or absence of superscripts, as described above). Columns A, J, T, and % refer to living mussels collected by the Academy in 1977.

Column Headings

A - Adult specimen(s)

J - Juvenile specimen(s) (i.e., mussels bysally attached to the brail)

T - Total of A and J

% - The proportion expressed as percentage that the specimens of the given taxon are of all mussels collected at the given site.

R - Recent presence records (i.e., for the period during or since the Finke (1966) survey in 1965)*

H - Historical occurrence records (i.e., for the period prior to 1965)**

* An "x" without a superscript in the "R" column denotes 1977 discovery by the Academy of recently dead mussel shells.

** An "x" without a superscript in the "H" column denotes 1977 discovery by the Academy of long-dead shells.

Superscript (upper case only)

A - Grier and Mueller (1922-1923)

B - F. C. Baker (1903)

C - Davis and Cawley (1975)

D - Dawley (1947)

E - Ellis' (1931a, 1931b) records, synopsized by van der Schalie and van der Schalie (1950)

F - Finke (1966)

G - Gale (1969)

H - M. E. Havlik (personal communication)

I - Coker (1919)

K - Ecology Consultants (1977)

L - L. Halversen (personal communication)

M - Marking and Bills (1977)

N - National Biocentric (1977)

O - R. Oesch (personal communication)

P - Perry (1978)

Q - Shimek (1888)

S - Fuller (1977a)

T - T. M. Freitag (personal communication, Rock Island District, Corps of Engineers)

V - Havlik and Stansbery (1978)

W - Wisconsin Department of Natural Resources 1977-1978 Upper Mississippi River mussel survey

Y - Cawley (1977)

Z - S. D. Hinz (personal communication, Iowa-Illinois Gas and Electric Company)

Certain data in the following Exhibits are queried. Questionable records represented by "?x^E" are Ellis survey discoveries whose ascription to modern Pools is not possible on the basis of the van der Schalies' (1950) synopsis; those represented by "?x^P" are of Perry (1978) survey dead shells whose antiquity (in terms of "R" or "H") has not been ascertained. Other questionable records are equivocal because the identities of the corresponding shells are uncertain. Totals of records are queried if at least one of the summed items is in question in some respect.

Five very rare Upper Mississippi River drainage naiad species require additional commentory here. A natural history of each has been provided already (see Results and Discussion: Taxa, above): *Uniomerus tetralasmus*, *Proptera purpurata*, *Ligumia subrostrata*, *Dysnomia triquetra*, and *Alasmidonta calceola*.

Uniomerus tetralasmus is omitted from the following Exhibits because it has never been recorded from the mainstem Upper Mississippi. However, its eventual discovery there is very likely because that waterway provides habitats appropriate to this species. It is considered Rare in Missouri (Nordstrom et al., 1977).

Proptera purpurata is omitted from the following Exhibits because it was not until after Appendix C had been prepared that the Principal Investigator learned of Perry's (1978) discovery of Purple Pocketbook in the reach of the Upper Mississippi River that is called Below Pool 27 in this report. As *Potamilus purpuratus*, this species is considered Rare in Missouri (Nordstrom et al., 1977).

Ligumia subrostrata is listed in the following exhibits because of Coker's (1919) record from "the Mississippi River" (probably near the then Bureau of Fisheries mussel propagation laboratory at Fairport, Iowa, in the modern Pool 16); Shimek's (1888) statement that this species is "very common in ponds, creeks, etc., ...along the Mississippi"; and the specimen(s) recorded by Grier and Mueller (1922-1923) from Fountain City, Wisconsin (Pool 5A).

Dysnomia triquetra is omitted from the following Exhibits because the Principal Investigator did not become aware of relevant records until Appendix C had been completed. Grier and Mueller (1922-1923) listed this species from Lake Pepin in the modern Pool 4 and from Fairport, Iowa (Pool 16). Johnson (1978) recorded the animal from Davenport and Muscatine, Iowa; these localities are today in Pools 14, 15, and/

or 16. As *Epioblasma triquetra* this species is considered Rare in Missouri (Nordstrom et al., 1977). Johnson's belief that *D. triquetra* should be called *Plagiola (Truncillopsis) triquetra* is plausible.

Alasmidonta calceola is omitted from the following Exhibits, but is now admitted to this report on the strength of Shimek's (1888) listing the species (as *Unio triangularis* Barnes) "in the Mississippi" and of the record in Grier and Mueller (1922-1923) for Fountain City, Wisconsin, in the modern Pool 5A.

Certain totals in the following Exhibits may or should be adjusted in the light of the foregoing records.

Totals given for juveniles of two pairs of species (*Truncilla truncata* and *T. donaciformis; Lampsilis ovata ventricosa* and *L. radiata siliquoidea*) are equivocal because of uncertainty about morphological discriminants between post-larval stages within each pair of congeners. The large totals of putative juvenile *T. donaciformis* probably are valid claims, nevertheless, because of the comparative rarity of adult *T. truncata* and the latter species' obvious lesser recruitment.

Exhibit 49

Study Area

Site data: Exhibits 4-46

		A	J	T	%	R	H
x	<u>Cumberlandia</u> <u>monodonta</u>	6		6	0.07	x^Z	x^Q
x	<u>Quadrula</u> <u>metanevra</u>	26		26	0.31	x^F	x^E
x	<u>Q</u>. <u>quadrula</u>	498	2	500	5.88	x^F	x^E
x	<u>Q</u>. <u>nodulata</u>	321		321	3.78	x^Z	x^E
x	<u>Q</u>. <u>pustulosa</u>	748		748	8.80	x^F	x^E
x	<u>Tritogonia</u> <u>verrucosa</u>	7		7	0.08	x^F	x^E
	<u>Cyclonaias</u> <u>tuberculata</u>						x^E
x	<u>Fusconaia</u> <u>flava</u>	331	3	334	3.93	x^F	x^E
	<u>F</u>. <u>ebena</u>					x^F	x^E
x	<u>Megalonaias</u> <u>gigantea</u>	210		210	2.47	x^F	x^E
x	<u>Amblema</u> <u>plicata</u>	3009	16	3025	35.58	x^F	x^E
	<u>Plethobasus</u> <u>cyphyus</u>					x^T	x^E
x	<u>Pleurobema</u> <u>cordatum</u>	11		11	0.13	x^H	x^E
x	<u>Elliptio</u> <u>crassidens</u>	5		5	0.06		x^E
x	<u>E</u>. <u>dilatata</u>	123		123	1.45	x^F	x^E
x	<u>Obliquaria</u> <u>reflexa</u>	270		270	3.18	x^F	x^E
x	<u>Proptera</u> <u>alata</u>	119		119	1.40	x^F	x^E
x	<u>P</u>. <u>laevissima</u>	57	5	62	0.73	x^F	x^E
	<u>P</u>. <u>capax</u>						xE
x	<u>Leptodea</u> <u>fragilis</u>	32	73	105	1.24	x^F	x^E
	<u>L</u>. <u>leptodon</u>						x^B

		A	J	T	%	R	H
x	Ellipsaria lineolata	39		39	0.46	x^F	x^E
x	Truncilla truncata	213		213	2.51	x^F	x^E
x	T. donaciformis	254	894	1148	13.50	x^Z	x^E
x	Obovaria olivaria	433		433	5.09	x^F	x^E
x	Actinonaias carinata	30		30	0.35	x^Z	x^E
	A. ellipsiformis						x^E
x	Ligumia recta	17	2	19	0.22	x^F	x^E
	L. subrostrata						x^I
x	Carunculina parva	9	181	190	2.23	x^G	x^E
x	Lampsilis teres	18		18	0.21	x^F	x^E
x	L. higginsi	3		3	0.04	x^F	x^E
x	L. radiata siliquoidea	23		23	0.27	x^F	x^E
x	L. ovata ventricosa	98	9	107	1.26	x^F	x^E
x	Arcidens confragosus	45		45	0.53	x^Z	x^E
x	Lasmigona complanata	16	1	17	0.20	x^Z	x^E
x^T	L. costata					x^H	x^D
	L. compressa					x^P	
	Alasmidonta marginata						x^E
	Simpsoniconcha ambigua						x^E
x^N	Anodontoides ferussacianus						x^D
x^T	Anodonta suborbiculata					x^T	x^I
x	A. imbecillis	166	2	168	1.98	x^H	x^E
x	A. grandis	162		162	1.91	x^F	x^E
x	Strophitus undulatus	15		15	0.18	x^F	x^E
35		7314	1188	8502	100.03	36	44

Exhibit 50

Minnesota River

Site data: Exhibit 4

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						x^D
Q. nodulata						
Q. pustulosa						x^D
Tritogonia verrucosa						x^D
Cyclonaias tuberculata						
Fusconaia flava						x^D
F. ebena						
Megalonaias gigantea						x^D
Amblema plicata						x^D
Plethobasus cyphyus						x^D
Pleurobema cordatum						x^D
Elliptio crassidens						x^D
E. dilatata						x^D
Obliquaria reflexa						x^D
Proptera alata						x^D
P. laevissima						x^D
P. capax						
Leptodea fragilis						x^D
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						x^D
Truncilla truncata						x^D
T. donaciformis						x^D
Obovaria olivaria						x^D
Actinonaias carinata						x^D
A. ellipsiformis						
Ligumia recta						x^D
L. subrostrata						
Carunculina parva						x^D
Lampsilis teres						x^D
L. higginsi						x^D
L. radiata siliquoidea						x^D
L. ovata ventricosa						x^D
Arcidens confragosus						x^D
Lasmigona complanata						x^D
L. costata						x^D
L. compressa						
Alasmidonta marginata						x^D
Simpsoniconcha ambigua						
Anodontoides ferussacianus						x^D
Anodonta suborbiculata						
A. imbecillis						x^D
A. grandis						x^D
Strophitus undulatus						

Exhibit 51

St. Croix River

Site data: Exhibit 5

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	Quadrula metanevra	2		2	0.37		
x	Q. quadrula	2		2	0.37		
	Q. nodulata						
x	Q. pustulosa	26		26	4.76		x^D
x	Tritogonia verrucosa	7		7	1.28		x^D
	Cyclonaias tuberculata						x^D
x	Fusconaia flava	71	1	72	13.19		x^D
	F. ebena						
	Megalonaias gigantea						x^D
x	Amblema plicata	266		266	48.72		x^D
	Plethobasus cyphyus						x^D
x	Pleurobema cordatum	9		9	1.65		x^D
x	Elliptio crassidens	4		4	0.73		
x	E. dilatata	37		37	6.78		x^D
x	Obliquaria reflexa	27		27	4.95		x^D
x	Proptera alata	9		9	1.65		x^D
	P. laevissima						x^D
	P. capax						
x	Leptodea fragilis	2	2	4	0.73		x^D
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	1		1	0.18		
x	Truncilla truncata	2		2	0.37		x^D
x	T. donaciformis	13	5	18	3.30		
x	Obovaria olivaria	1		1	0.18		x^D
x	Actinonaias carinata	2		2	0.37		x^D
	A. ellipsiformis						
	Ligumia recta						x^D
	L. subrostrata					?x	
	Carunculina parva						x^D
	Lampsilis teres						
x	L. higginsi	2		2	0.37		x^D
x	L. radiata siliquoidea	17		17	3.11		x^D
x	L. ovata ventricosa	21	1	22	4.03		x^D
	Arcidens confragosus						
x	Lasmigona complanata	7		7	1.28		x^D
	L. costata					x	
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x	x^D
x	A. grandis	8		8	1.47		x^D
x	Strophitus undulatus	1		1	0.18		x^D
23		537	9	546	100.02	3?	25

Exhibit 52

Hudson RR Bridge

Site data: Exhibit 5

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	Quadrula metanevra	2		2	0.37		
x	Q. quadrula	2		2	0.37		
	Q. nodulata						
x	Q. pustulosa	26		26	4.76		x^D
x	Tritogonia verrucosa	7		7	1.28		x^D
	Cyclonaias tuberculata						x^D
x	Fusconaia flava	71	1	72	13.19		x^D
	F. ebena						
	Megalonaias gigantea						x^D
x	Amblema plicata	266		266	48.72		x^D
	Plethobasus cyphyus						
x	Pleurobema cordatum	9		9	1.65		
x	Elliptio crassidens	4		4	0.73		
x	E. dilatata	37		37	6.78		
x	Obliquaria reflexa	27		27	4.95		x^D
x	Proptera alata	9		9	1.65		x^D
	P. laevissima						
	P. capax						
x	Leptodea fragilis	2	2	4	0.73		x^D
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	1		1	0.18		x^D
x	Truncilla truncata	2		2	0.37		x^D
x	T. donaciformis	13	5	18	3.30		
x	Obovaria olivaria	1		1	0.18		
x	Actinonaias carinata	2		2	0.37		
	A. ellipsiformis						
	Ligumia recta						x^D
	L. subrostrata					?x	
	Carunculina parva						
	Lampsilis teres						
x	L. higginsi	2		2	0.37		x^D
x	L. radiata siliquoidea	17		17	3.11		x^D
x	L. ovata ventricosa	21	1	22	4.03		
	Arcidens confragosus						
x	Lasmigona complanata	7		7	1.28		x^D
	L. costata					x	
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x	
x	A. grandis	8		8	1.47		x^D
x	Strophitus undulatus	1		1	0.18		x^D
23		537	9	546	100.02	3?	16

Exhibit 53

Upper Mississippi River

Site data: Exhibits 6-46

		A	J	T	%	R	H
x	<u>Cumberlandia</u> <u>monodonta</u>	6		6	0.08	x^F	x^E
x	<u>Quadrula</u> <u>metanevra</u>	24		24	0.30	x^F	x^E
x	<u>Q.</u> <u>quadrula</u>	496	2	498	6.26	x^F	x^E
x	<u>Q.</u> <u>nodulata</u>	321		321	4.03	x^F	x^E
x	<u>Q.</u> <u>pustulosa</u>	722		722	9.07	x^F	x^E
	<u>Tritogonia</u> <u>verrucosa</u>					x^F	x^E
	<u>Cyclonaias</u> <u>tuberculata</u>						x^E
x	<u>Fusconaia</u> <u>flava</u>	260	2	262	3.29	x^F	x^E
	<u>F.</u> <u>ebena</u>					x^F	x^E
x	<u>Megalonaias</u> <u>gigantea</u>	210		210	2.64	x^F	x^E
x	<u>Amblema</u> <u>plicata</u>	2743	16	2759	34.68	x^F	x^E
	<u>Plethobasus</u> <u>cyphyus</u>					x^F	x^E
	<u>Pleurobema</u> <u>cordatum</u>	2		2	0.03	x^H	x^E
x	<u>Elliptio</u> <u>crassidens</u>	1		1	0.01		x^E
x	<u>E.</u> <u>dilatata</u>	86		86	1.08	x^F	x^E
x	<u>Obliquaria</u> <u>reflexa</u>	243		243	3.05	x^F	x^E
x	<u>Proptera</u> <u>alata</u>	110		110	1.38	x^F	x^E
x	<u>P.</u> <u>laevissima</u>	57	5	62	0.78	x^F	x^E
	<u>P.</u> <u>capax</u>						x^E
x	<u>Leptodea</u> <u>fragilis</u>	30	71	101	1.27	x^F	x^E
	<u>L.</u> <u>leptodon</u>						x^E

		A	J	T	%	R	H
x	Ellipsaria lineolata	38		38	0.48	x[F]	x[E]
x	Truncilla truncata	211		211	2.65	x[F]	x[E]
x	T. donaciformis	241	889	1130	14.20	x[Z]	x[E]
x	Obovaria olivaria	432		432	5.43	x[F]	x[E]
x	Actinonaias carinata	28		28	0.35	x[Z]	x[E]
	A. ellipsiformis						x[E]
x	Ligumia recta	17	2	19	0.24	x[F]	x[E]
	L. subrostrata						x[I]
x	Carunculina parva	9	181	190	2.36	x[G]	x[E]
x	Lampsilis teres	18		18	0.23	x[F]	x[E]
x	L. higginsi	1		1	0.01	x[F]	x[E]
x	L. radiata siliquoidea	6		6	0.08	x[F]	x[E]
x	L. ovata ventricosa	77	8	85	1.07	x[F]	x[E]
x	Arcidens confragosus	45		45	0.57	x[Z]	x[E]
x	Lasmigona complanata	9	1	10	0.13	x[Z]	x[E]
x[T]	L. costata					x[H]	x[D]
	L. compressa					x[P]	
	Alasmidonta marginata						x[E]
	Simpsoniconcha ambigua						x[E]
x[N]	Anodontoides ferussacianus						x[D]
x[T]	Anodonta suborbiculata					x[T]	x[I]
x	A. imbecillis	166	2	168	2.11	x[H]	x[E]
x	A. grandis	154		154	1.94	x[F]	x[E]
x	Strophitus undulatus	14		14	0.18	x[F]	x[E]
33		6777	1179	7956	100.01	36	44

Exhibit 54

Upper St. Anthony Falls Pool

Site data: Exhibits 6-7

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
Q. nodulata						
Q. pustulosa						
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea						
Amblema plicata						
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						
Proptera alata						
P. laevissima						
P. capax						
Leptodea fragilis						
L. leptodon						

	A	J	T	%	R	E
Ellipsaria lineolata						
Truncilla truncata						
T. donaciformis						
Obovaria olivaria						
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						

Exhibit 55

Lower St. Anthony Falls Pool

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
Q. nodulata						
Q. pustulosa						
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea						
Amblema plicata						
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						
Proptera alata						
P. laevissima						
P. capax						
Leptodea fragilis						
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						
Truncilla truncata						
T. donaciformis						
Obovaria olivaria						
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						

Exhibit 56

Pool 1

Site data: Exhibits 8-10

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
Q. nodulata						
Q. pustulosa						
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea						
Amblema plicata						
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						
Proptera alata						
P. laevissima						
P. capax						
Leptodea fragilis						x
L. leptodon						

	A	J	T	S	R	H
Ellipsaria lineolata						
Truncilla truncata						x
T. donaciformis						
Obovaria olivaria						
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						x
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						

3

Exhibit 57

Pool 2

Site data: Exhibits 10-13

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						x^D
	Q. quadrula						x^D
	Q. nodulata						
	Q. pustulosa						x^D
	Tritogonia verrucosa						x^D
	Cyclonaias tuberculata						
x	*Fusconaia flava*	1		1	5.00		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	2		2	10.00		x
	Plethobasus cyphyus						
	Pleurobema cordatum						x
	Elliptio crassidens						
	E. dilatata						x^D
	Obliquaria reflexa						
	Proptera alata						x^D
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*	1		1	5.00		x
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						x^D
x	Truncilla truncata	4		4	20.00		x^D
	T. donaciformis						
	Obovaria olivaria						?x
x	Actinonaias carinata	2		2	10.00		x^D
	A. ellipsiformis						
x	Ligumia recta	1		1	5.00		?x
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						?x
	L. higginsi						?x
x	L. radiata siliquoidea	3		3	15.00		
x	L. ovata ventricosa	4		4	20.00		x^D
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
x	Strophitus undulatus	2		2	10.00		
9		20		20	100.00	17?	

Exhibit 58

Lock and Dam 1

Site data: Exhibit 10

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
	Q. pustulosa						
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	1		1	5.00		
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	2		2	10.00		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
	Obliquaria reflexa						
	Proptera alata						
	P. laevissima						
	P. capax						
x	Leptodea fragilis	1		1	5.00		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	Truncilla truncata	4		4	20.00		
	T. donaciformis						
	Obovaria olivaria						
x	Actinonaias carinata	2		2	10.00		
	A. ellipsiformis						
x	Ligumia recta	1		1	5.00		
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
x	L. radiata siliquoidea	3		3	15.00		
x	L. ovata ventricosa	4		4	20.00		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
x	Strophitus undulatus	2		2	10.00		
9		20		20	100.00		

Exhibit 59

Pool 3

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
Q. nodulata						
Q. pustulosa						
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea						
Amblema plicata						
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						
Proptera alata						
P. laevissima						
P. capax						
Leptodea fragilis						
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						
Truncilla truncata						
T. donaciformis						
Obovaria olivaria						
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						

Exhibit 60

Pool 4

Site data: Exhibits 14-17

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						x[E]
	Q. quadrula						x[D]
	Q. nodulata						
x	*Q. pustulosa*	2		2	2.77	x[F]	x[E]
	Tritogonia verrucosa						x[E]
	Cyclonaias tuberculata						x[E]
x	*Fusconaia flava*	4		4	5.55	x[F]	x[E]
	F. ebena						x[E]
	Megalonaias gigantea						x[E]
x	*Amblema plicata*	17		17	23.61	x[F]	x[E]
	Plethobasus cyphyus						x[E]
x	*Pleurobema cordatum*	1		1	1.39		x[E]
	Elliptio crassidens						x[E]
x	*E. dilatata*	2		2	2.77	x[F]	x[E]
x	*Obliquaria reflexa*	2		2	2.77		x[E]
	Proptera alata					x[F]	x[E]
	P. laevissima						x[E]
	P. capax						x[E]
	Leptodea fragilis					x[F]	x[E]
	L. leptodon						

AD-A109 982 ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA PA DIV OF--ETC F/G 6/6
FRESH-WATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE) OF THE UPPE--ETC(U)
JUN 78 S L FULLER
UNCLASSIFIED 78-33 NL

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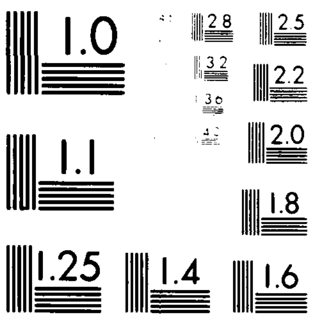

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU [illegible] STANDARDS [illegible]

		A	J	T	%	R	H
	Ellipsaria lineolata					x^F	x^E
x	*Truncilla truncata*						x^E
x	*T. donaciformis*		37	37	51.39		x^E
x	*Obovaria olivaria*	1		1	1.39		x^E
	Actinonaias carinata						x^E
	A. ellipsiformis						x^E
x	*Ligumia recta*	1		1	1.39	x^F	x^E
	L. subrostrata						
x	*Carunculina parva*		3	3	4.17		x^E
	Lampsilis teres					x^F	x^E
	L. higginsi						x^D
	L. radiata siliquoidea					x^F	x^E
x	*L. ovata ventricosa*		1	1	1.39	x^F	x^E
	Arcidens confragosus						x^D
	Lasmigona complanata						x^E
	L. costata						x^D
	L. compressa						
	Alasmidonta marginata						x^E
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						x^D
x	*A. grandis*	1		1	1.39	?x^F	x^E
	Strophitus undulatus						x^E
13		31	41	72	99.98	12?	37

Exhibit 61

Lake City Small Boat Harbor Entrance

Site data: Exhibit 14

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						x D
	Q. quadrula						x D
	Q. nodulata						
	Q. pustulosa						
	Tritogonia verrucosa						x D
	Cyclonaias tuberculata						
	Fusconaia flava						x D
	F. ebena						x D
	Megalonaias gigantea						x D
x	Amblema plicata	2		2	50.00		x D
	Plethobasus cyphyus						
	Pleurobema cordatum						x D
	Elliptio crassidens						x D
	E. dilatata						x D
	Obliquaria reflexa						x D
	Proptera alata						x D
	P. laevissima						x D
	P. capax						
	Leptodea fragilis						x D
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						x^D
	Truncilla truncata						x^D
	T. donaciformis						
	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
x	Ligumia recta	1		1	25.00		x^D
	L. subrostrata						
	Carunculina parva						x^D
	Lampsilis teres						x^D
	L. higginsi						
	L. radiata siliquoidea						x^D
	L. ovata ventricosa						x^D
	Arcidens confragosus						
	Lasmigona complanata						x^D
	L. costata						x^D
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						x^D
x	A. grandis	1		1	25.00		x^D
	Strophitus undulatus						x^D
3		4		4	100.00		26

Exhibit 62

Reads Landing

Site data: Exhibit 15

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
	Q. pustulosa					x	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	1		1	6.25	x^{L}	
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	6		6	37.50	x^{S}	
	Plethobasus cyphyus						
	Pleurobema cordatum					x	
	Elliptio crassidens						
x	E. dilatata	2		2	12.50	x^{L}	
	Obliquaria reflexa					x^{L}	
	Proptera alata					x^{L}	
	P. laevissima					x^{L}	
	P. capax						
	Leptodea fragilis					x^{L}	
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata					x^L	
x	*T. donaciformis*		6	6	37.50	x^S	
	Obovaria olivaria					x	
	Actinonaias carinata					x^L	
	A. ellipsiformis						
	Ligumia recta					x^L	
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea					x^L	
x	*L. ovata ventricosa*		1	1	6.25	x^S	
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x^L	
	A. grandis					x^L	
	Strophitus undulatus					x^L	
5		9	7	16	100.00	19	

Exhibit 63

Teepeeota Point

Site data: Exhibit 16

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
x	*Q. pustulosa*	1		1	3.85		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	1		1	3.85		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	9		9	34.62		
	Plethobasus cyphyus						
x	*Pleurobema cordatum*	1		1	3.85		
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	2		2	7.69		
	Proptera alata						
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata					x	
x	T. donaciformis		10	10	38.46		
x	Obovaria olivaria	1		1	3.85		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	Carunculina parva		1	1	3.85		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa					x	
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
8		15	11	26	100.02	2	

Exhibit 64

Grand Encampment

Site data: Exhibit 17

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
x	Q. pustulosa	1		1	3.85		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	2		2	7.69		
	F. ebena						
	Megalonaias gigantea						
	Amblema plicata						
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
	Obliquaria reflexa						
	Proptera alata						
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
x	*T. donaciformis*		21	21	80.77		
	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*		2	2	7.69		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x	
	A. grandis						
	Strophitus undulatus						
4		3	23	26	100.00	1	

Exhibit 65

Pool 5

Site data: Exhibit 18-20

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
x	Q. pustulosa	7		7	1.02	x	x^D
	Tritogonia verrucosa						x^D
	Cyclonaias tuberculata						
x	Fusconaia flava	3		3	0.44	x	x^D
	F. ebena						x^D
	Megalonaias gigantea						
x	Amblema plicata	20	2	22	3.19	x	
	Plethobasus cyphyus						x^D
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						x^D
x	Obliquaria reflexa	2		2	0.29	x	x^D
	Proptera alata					x	
x	P. laevissima	2	1	3	0.44	x^F	
	P. capax						
x	Leptodea fragilis	1	2	3	0.44	x	
	L. leptodon						

		A	J	T	%	R	H
	<u>Ellipsaria lineolata</u>					x^F	x^D
	<u>Truncilla truncata</u>						
x	<u>T. donaciformis</u>	4	566	570	82.73	x	
x	<u>Obovaria olivaria</u>	1		1	0.15	x^A	
	<u>Actinonaias carinata</u>						x^D
	<u>A. ellipsiformis</u>						
x	<u>Ligumia recta</u>		1	1	0.15	x^F	x^D
	<u>L. subrostrata</u>						
x	<u>Carunculina parva</u>	5	68	73	10.60		
	<u>Lampsilis teres</u>						
	<u>L. higginsi</u>						
x	<u>L. radiata siliquoidea</u>	1		1	0.15	x	x^D
x	<u>L. ovata ventricosa</u>	2		2	0.29	x	x^D
	<u>Arcidens confragosus</u>						x^D
	<u>Lasmigona complanata</u>						x^D
	<u>L. costata</u>						x^D
	<u>L. compressa</u>						
	<u>Alasmidonta marginata</u>						
	<u>Simpsoniconcha ambigua</u>						
	<u>Anodontoides ferussacianus</u>						
	<u>Anodonta suborbiculata</u>						
x	<u>A. imbecillis</u>	1		1	0.15		
	<u>A. grandis</u>					x	
	<u>Strophitus undulatus</u>					x^F	
13		49	640	689	100.04	15	15

		A	J	T	%	R	H
	<u>Ellipsaria lineolata</u>						
	<u>Truncilla truncata</u>						
x	<u>T. donaciformis</u>	3	352	355	83.14	x	
x	<u>Obovaria olivaria</u>	1		1	0.47	x	
	<u>Actinonaias carinata</u>						
	<u>A. ellipsiformis</u>						
x	<u>Ligumia recta</u>		1	1	0.47		
	<u>L. subrostrata</u>						
x	<u>Carunculina parva</u>		63	63	14.75		
	<u>Lampsilis teres</u>						
	<u>L. higginsi</u>						
	<u>L. radiata siliquoidea</u>					x	
	<u>L. ovata ventricosa</u>					x	
	<u>Arcidens confragosus</u>						
	<u>Lasmigona complanata</u>						
	<u>L. costata</u>						
	<u>L. compressa</u>						
	<u>Alasmidonta marginata</u>						
	<u>Simpsoniconcha ambigua</u>						
	<u>Anodontoides ferussacianus</u>						
	<u>Anodonta suborbiculata</u>						
	<u>A. imbecillis</u>						
	<u>A. grandis</u>						
	<u>Strophitus undulatus</u>						
8		9	418	427	100.47	10	

Exhibit 67

Weaver Bottom

Site data: Exhibit 19

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
	Q. pustulosa						
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	1		1	0.44		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	1	1	2	0.88		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
	Obliquaria reflexa						
	Proptera alata						
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*		2	2	0.88		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
x	*T. donaciformis*		214	214	95.11		
	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*		5	5	2.22		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	1		1	0.44		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
6		3	222	225	99.97		

Exhibit 68

Lock and Dam 5 Culvert Construction

Site data: Exhibit 20

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
x	*Q. pustulosa*	5		5	13.51		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	2		2	5.41		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	18		18	48.65		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	1		1	2.70		
	Proptera alata						
x	*P. laevissima*	1		1	2.70		
	P. capax						
x	*Leptodea fragilis*	1		1	2.70		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
x	*T. donaciformis*	1		1	2.70		
	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*	5		5	13.51		
	Lampsilis teres						
	L. higginsi						
x	*L. radiata siliquoidea*	1		1	2.70		
	L. ovata ventricosa						
	Arcidens confragosus	1		1	2.70		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	*A. imbecillis*	1		1	2.70		
	A. grandis					x	
	Strophitus undulatus						
10		37		37	99.98	1	

Exhibit 69

Pool 5A

Site data: None

		A	J	T	%	R	H
	<u>Cumberlandia</u> <u>monodonta</u>						
	<u>Quadrula</u> <u>metanevra</u>					x^W	
	<u>Q.</u> <u>quadrula</u>						
	<u>Q.</u> <u>nodulata</u>						
x^W	<u>Q.</u> <u>pustulosa</u>						
	<u>Tritogonia</u> <u>verrucosa</u>						
	<u>Cyclonaias</u> <u>tuberculata</u>						
x^W	<u>Fusconaia</u> <u>flava</u>						
	<u>F.</u> <u>ebena</u>						
	<u>Megalonaias</u> <u>gigantea</u>						
x^W	<u>Amblema</u> <u>plicata</u>						
	<u>Plethobasus</u> <u>cyphyus</u>						
	<u>Pleurobema</u> <u>cordatum</u>						
	<u>Elliptio</u> <u>crassidens</u>						
	<u>E.</u> <u>dilatata</u>						
x^W	<u>Obliquaria</u> <u>reflexa</u>						
	<u>Proptera</u> <u>alata</u>					x^W	
	<u>P.</u> <u>laevissima</u>						
	<u>P.</u> <u>capax</u>						
x^W	<u>Leptodea</u> <u>fragilis</u>						
	<u>L.</u> <u>leptodon</u>						

		A	J	T	%	R	H
x^W	Ellipsaria lineolata						
	Truncilla truncata						
x^W	T. donaciformis						
x^W	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x^S	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x^W	L. ovata ventricosa						
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x^W	A. grandis						
x^W	Strophitus undulatus						
12						2	

Exhibit 70

Pool 6

Site data: None

		A	J	T	%	R	H
	Cumberlandia monodonta						
x^W	Quadrula metanevra						x^D
	Q. quadrula						
	Q. nodulata						
x^S	Q. pustulosa					x^F	x^D
	Tritogonia verrucosa					x^W	x^D
	Cyclonaias tuberculata						
x^S	Fusconaia flava					x^F	x^D
	F. ebena					x^F	x^D
	Megalonaias gigantea						x^D
x^S	Amblema plicata					x^F	x^D
	Plethobasus cyphyus						
	Pleurobema cordatum					x^W	
	Elliptio crassidens						x^D
x^W	E. dilatata					x^F	x^D
x^W	Obliquaria reflexa					x^F	
x^S	Proptera alata						x^D
x^W	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata					x^W	
x^W	Truncilla truncata						x^D
x^S	T. donaciformis						
x^W	Obovaria olivaria					x^F	x^D
	Actinonaias carinata						x^D
	A. ellipsiformis						
x^W	Ligumia recta					x^F	x^D
	L. subrostrata						
x^S	Carunculina parva						
	Lampsilis teres					x^F	
	L. higginsi						
	L. radiata siliquoidea						x^D
x^W	L. ovata ventricosa					x^F	x^D
	Arcidens confragosus						
	Lasmigona complanata						x^D
	L. costata						x^D
	L. compressa						
	Alasmidonta marginata						x^D
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x^W	A. grandis					x^F	x^D
	Strophitus undulatus						
15						14	20

Exhibit 71

Pool 7

Site data: None

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra					x^H	x^D
	Q. quadrula					x^H	
	Q. nodulata					x^H	
x^S	*Q. pustulosa*					x^H	x^D
	Tritogonia verrucosa					x^H	x^D
	Cyclonaias tuberculata						
x^S	*Fusconaia flava*					x^H	
	F. ebena						x^D
	Megalonaias gigantea					x^W	
x^S	*Amblema plicata*					x^H	x^D
	Plethobasus cyphyus						x^D
	Pleurobema cordatum					x^W	
	Elliptio crassidens						x^H
x^W	*E. dilatata*					x^H	
x^W	*Obliquaria reflexa*					x^H	x^D
x^S	*Proptera alata*					x^H	x^D
	P. laevissima					x^H	
	P. capax						
x^S	*Leptodea fragilis*					x^H	
	L. leptodon						

		A	J	T	%	R	H
x^W	*Ellipsaria lineolata*					x^F	
x^W	*Truncilla truncata*					x^H	
x^S	*T. donaciformis*					x^H	
x^W	*Obovaria olivaria*					x^H	x^D
	Actinonaias carinata					x^W	x^D
	A. ellipsiformis						
x^W	*Ligumia recta*					x^H	x^D
	L. subrostrata						
x^S	*Carunculina parva*					x^H	
	Lampsilis teres						
	L. higginsi					x^F	x^D
x^M	*L. radiata siliquoidea*					x^H	x^D
x^S	*L. ovata ventricosa*					x^H	x^D
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						x^W
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x^H	
x^W	*A. grandis*					x^H	
	Strophitus undulatus					x^W	
16						27	16

Exhibit 72

Pool 8

Site data: Exhibits 21-22

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	*Quadrula metanevra*	1		1	0.35		
x	*Q. quadrula*	7		7	2.45	x^{H}	
x	*Q. nodulata*	1		1	0.35	x^{H}	
x	*Q. pustulosa*	15		15	5.24	x^{H}	
	Tritogonia verrucosa					x^{W}	
	Cyclonaias tuberculata						
x	*Fusconaia flava*	7	1	8	2.80	x^{H}	
	F. ebena						x^{H}
	Megalonaias gigantea						
x	*Amblema plicata*	26		26	9.09	x^{H}	
	Plethobasus cyphyus						x^{H}
	Pleurobema cordatum					x^{W}	x^{H}
	Elliptio crassidens						x^{H}
	E. dilatata					x^{W}	x^{H}
x	*Obliquaria reflexa*	10		10	3.50	x^{H}	
x	*Proptera alata*	2		2	0.70	x^{H}	
x^{W}	*P. laevissima*					x^{H}	
	P. capax						
x	*Leptodea fragilis*		22	22	7.69	x^{H}	
	L. leptodon						

		A	J	T	%	R	H
x^{W}	*Ellipsaria lineolata*						
x	*Truncilla truncata*	3		3	1.05	x^{H}	
x	*T. donaciformis*	4	19	23	8.04	x^{H}	
x	*Obovaria olivaria*	4		4	1.40	x^{H}	
	Actinonaias carinata					x^{W}	
	A. ellipsiformis						
x^{W}	*Ligumia recta*					x^{H}	
	L. subrostrata						
x	*Carunculina parva*		154	154	53.85	x^{H}	
	Lampsilis teres						
x^{H}	*L. higginsi*						
	L. radiata siliquoidea					x^{H}	
x	*L. ovata ventricosa*	3	3	6	2.10	x^{H}	
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	4		4	1.40		
	Strophitus undulatus						
19		87	199	286	100.01	20	5

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
x	*T. donaciformis*	3	11	14	10.85		
x	*Obovaria olivaria*	3		3	2.33		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*		55	55	42.64		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	2	2	4	3.10		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	2		2	1.55		
	Strophitus undulatus						
13		61	68	129	100.03		

Exhibit 74

Brownsville

Site data: Exhibit 22

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	*Q. quadrula*	3		3	1.91		
	Q. nodulata						
x	*Q. pustulosa*	4		4	2.55		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	2	1	3	1.91		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	5		5	3.18		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	3		3	1.91		
x	*Proptera alata*	1		1	0.64		
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*		22	22	14.01		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	*Truncilla truncata*	3		3	1.91		
x	*T. donaciformis*	1	8	9	5.73		
x	*Obovaria olivaria*	1		1	0.64		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*		99	99	63.06		
	Lampsilis teres						
x[H]	*L. higginsi*						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	1	1	2	1.27		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	2		2	1.27		
	Strophitus undulatus						
14		26	131	157	99.99		

Exhibit 75

Pool 9

Site data: Exhibits 23-25

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	4		4	1.67	x[F]	
x	Q. nodulata	4		4	1.67	x[P]	
x	Q. pustulosa	12		12	5.02	x[F]	
	Tritogonia verrucosa					x[F]	
	Cyclonaias tuberculata						
x	Fusconaia flava	20		20	8.37	x[F]	
	F. ebena					x[F]	
x	Megalonaias gigantea	3		3	1.26	x[F]	
x	Amblema plicata	123	2	123	51.46	x[F]	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata					x[F]	
x	Obliquaria reflexa	4		4	1.67	x[F]	
x	Proptera alata	7		7	2.93	x[F]	
	P. laevissima						
	P. capax						
x	Leptodea fragilis	2		2	0.84	x[P]	
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata					x^F	
x	*Truncilla truncata*	5		5	2.09	x^F	
x	*T. donaciformis*	7	10	17	7.11		
x	*Obovaria olivaria*	17		17	7.11	x^F	
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta					x^F	
	L. subrostrata						
x	*Carunculina parva*		3	3	1.26		
	Lampsilis teres					x^F	
	L. higginsi						
	L. radiata siliquoidea					x^F	
x	*L. ovata ventricosa*	1		1	0.42	x^F	
	Arcidens confragosus						
x	*Lasmigona complanata*	2		2	0.84		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	15		15	6.28	x^F	
	Strophitus undulatus						
16		224	15	239	100.00	20	

Exhibit 76

Above Indian Camp Light

Site data: Exhibit 23

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	2		2	1.85		
x	Q. nodulata	2		2	1.85		
x	Q. pustulosa	6		6	5.55		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	8		8	7.41		
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	62	2	64	59.26		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	2		2	1.85		
x	Proptera alata	2		2	1.85		
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

	A	J	T	%	R	H
<u>Ellipsaria</u> <u>lineolata</u>						
<u>Truncilla</u> <u>truncata</u>						
x <u>T.</u> <u>donaciformis</u>	4	8	12	11.11		
x <u>Obovaria</u> <u>olivaria</u>	8		8	7.41		
<u>Actinonaias</u> <u>carinata</u>						
<u>A.</u> <u>ellipsiformis</u>						
<u>Ligumia</u> <u>recta</u>						
<u>L.</u> <u>subrostrata</u>						
<u>Carunculina</u> <u>parva</u>						
<u>Lampsilis</u> <u>teres</u>						
<u>L.</u> <u>higginsi</u>						
<u>L.</u> <u>radiata</u> <u>siliquoidea</u>						
<u>L.</u> <u>ovata</u> <u>ventricosa</u>						
<u>Arcidens</u> <u>confragosus</u>						
x <u>Lasmigona</u> <u>complanata</u>	2		2	1.85		
<u>L.</u> <u>costata</u>						
<u>L.</u> <u>compressa</u>						
<u>Alasmidonta</u> <u>marginata</u>						
<u>Simpsoniconcha</u> <u>ambigua</u>						
<u>Anodontoides</u> <u>ferussacianus</u>						
<u>Anodonta</u> <u>suborbiculata</u>						
<u>A.</u> <u>imbecillis</u>						
<u>A.</u> <u>grandis</u>						
<u>Strophitus</u> <u>undulatus</u>						
10	98	10	108	99.99		

Exhibit 77

Indian Camp Light

Site data: Exhibit 24

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
x Q. nodulata	1		1	3.33		
x Q. pustulosa	1		1	3.33		
Tritogonia verrucosa						
Cyclonaias tuberculata						
x Fusconaia flava	5		5	16.66		
F. ebena						
Megalonaias gigantea						
x Amblema plicata	11		11	36.66		
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
x Obliquaria reflexa	2		2	6.66		
Proptera alata						
P. laevissima						
P. capax						
x Leptodea fragilis	1		1	3.33		
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						
x Truncilla truncata	2		2	6.66		
x T. donaciformis	3	1	4	13.33		
x Obovaria olivaria	1		1	3.33		
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
x Carunculina parva		1	1	3.33		
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						
10	28	2	30	99.95		

Exhibit 78

Lansing Upper Light

Site data: Exhibit 25

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	*Q. quadrula*	2		2	1.98	x^P	
x	*Q. nodulata*	1		1	0.99	x^P	
x	*Q. pustulosa*	5		5	4.95	x^P	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	7		7	6.93	x^P	
	F. ebena						
x	*Megalonaias gigantea*	3		3	2.97	x^P	
x	*Amblema plicata*	48		48	47.52	x^P	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
	Obliquaria reflexa					x^P	
x	*Proptera alata*	5		5	4.95	x^P	
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*	1		1	0.99	x^P	
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	*Truncilla truncata*	3		3	2.97		
x	*T. donaciformis*		1	1	0.99		
x	*Obovaria olivaria*	8		8	7.92	x^P	
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta					x^P	
	L. subrostrata						
x	*Carunculina parva*		2	2	1.98		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea					x^P	
	L. ovata ?*ventricosa*					x^P	
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	15		15	14.85	x^P	
	Strophitus undulatus						
13		98	3	101	99.99	14	

Exhibit 79

Pool 10

Site data: Exhibit 26

		A	J	T	%	R	H
	Cumberlandia monodonta						x^{V}
x	Quadrula metanevra	5		5	0.27	x^{H}	x^{E}
x	Q. quadrula	29		29	1.57	x^{H}	x^{E}
x	Q. nodulata	3		3	0.16	x^{H}	x^{E}
x	Q. pustulosa	80		80	4.33	x^{H}	x^{E}
	Tritogonia verrucosa					x^{H}	x^{E}
	Cyclonaias tuberculata						x^{E}
x	Fusconaia flava	68		68	3.68	x^{H}	x^{E}
	F. ebena					x^{H}	x^{E}
x	Megalonaias gigantea	55		55	2.97	x^{H}	x^{E}
x	Amblema plicata	1324		1324	71.61	x^{H}	x^{E}
	Plethobasus cyphyus						x^{H}
x	Pleurobema cordatum	1		1	0.05	x^{H}	x^{V}
x	Elliptio crassidens	1		1	0.05		x^{H}
x	E. dilatata	65		65	3.52	x^{H}	x^{E}
x	Obliquaria reflexa	13		13	0.70	x^{H}	x^{E}
x	Proptera alata	11		11	0.59	x^{H}	x^{E}
x	P. laevissima		1	1	0.05	x^{H}	x^{V}
	P. capax						x^{E}
x	Leptodea fragilis	2		2	0.11	x^{H}	x^{E}
	L. leptodon						x^{V}

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	1		1	0.05	x[H]	x[E]
x	*Truncilla truncata*	21		21	1.14	x[H]	x[E]
x	*T. donaciformis*	5	4	9	0.49	x[H]	x[E]
x	*Obovaria olivaria*	82		82	4.43	x[H]	x[E]
x	*Actinonaias carinata*	1		1	0.05	x[H]	x[E]
	A. ellipsiformis						
x	*Ligumia recta*	9		9	0.49	x[H]	x[E]
	L. subrostrata						
x	*Carunculina parva*		14	14	0.76	x[H]	x[V]
	Lampsilis teres					x[H]	x[E]
x	*L. higginsi*	1		1	0.05	x[H]	x[E]
x	*L. radiata siliquoidea*	2		2	0.11	x[H]	x[E]
x	*L. ovata ventricosa*	12		12	0.65	x[H]	x[E]
x	*Arcidens confragosus*	16		16	0.87	x[H]	x[E]
	Lasmigona complanata					x[H]	x[V]
	L. costata					x[H]	x[V]
	L. compressa						
	Alasmidonta marginata						x[V]
	Simpsoniconcha ambigua						x[E]
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x[H]	x[E]
x	*A. grandis*	18		18	0.97	x[H]	x[E]
x	*Strophitus undulatus*	5		5	0.27	x[H]	x[E]
27		1830	19	1849	99.99	32	40

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	*Truncilla truncata*	6		6	0.98		
x	*T. donaciformis*	4	3	7	1.15		
x	*Obovaria olivaria*	7		7	1.15		
	Actinonaias carinata						
	A. ellipsiformis						
x	*Ligumia recta*	3		3	0.49		
	L. subrostrata						
x	*Carunculina parva*		14	14	2.30		
	Lampsilis teres						
	L. higginsi						
x	*L. radiata siliquoidea*	1		1	0.16		
x	*L. ovata ventricosa*	2		2	0.33		
x	*Arcidens confragosus*	2		2	0.33		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	6		6	0.98		
x	*Strophitus undulatus*	1		1	0.16		
20		592	18	610	99.98		

Exhibit 81

Prairie du Chien

Site data: None

		A	J	T	%	R	H
	Cumberlandia monodonta						x^{V}
x	Quadrula metanevra	5		5	0.40	x^{V}	x^{V}
x	Q. quadrula	24		24	1.94	x^{V}	x^{V}
x	Q. nodulata	1		1	0.08	x^{V}	x^{V}
x	Q. pustulosa	33		33	2.66	x^{V}	x^{V}
	Tritogonia verrucosa					x^{V}	x^{V}
	Cyclonaias tuberculata						x^{V}
x	Fusconaia flava	49		49	3.95	x^{V}	x^{V}
	F. ebena					x^{V}	x^{V}
x	Megalonaias gigantea	49		49	3.95	x^{V}	x^{V}
x	Amblema plicata	896		896	72.32	x^{V}	x^{V}
	Plethobasus cyphyus						x^{V}
x	Pleurobema cordatum	1		1	0.08	x^{V}	x^{V}
x	Elliptio crassidens	1		1	0.08		x^{V}
x	E. dilatata	28		28	2.26	x^{V}	x^{V}
x	Obliquaria reflexa	5		5	0.40	x^{V}	x^{V}
x	Proptera alata	3		3	0.24	x^{V}	x^{V}
	P. laevissima					x^{V}	x^{V}
	P. capax						x^{V}
x	Leptodea fragilis	2		2	0.16	x^{V}	x^{V}
	L. leptodon						x^{V}

		A	J	T	%	R	H
x	Ellipsaria lineolata	1		1	0.08	x^V	x^V
x	Truncilla truncata	15		15	1.21	x^V	x^V
x	T. donaciformis	1	1	2	0.16	x^V	x^V
x	Obovaria olivaria	75		75	6.05	x^V	x^V
x	Actinonaias carinata	1		1	0.08		x^V
	A. ellipsiformis						
x	Ligumia recta	6		6	0.48	x^V	x^V
	L. subrostrata						
	Carunculina parva					x^V	x^V
	Lampsilis teres					x^V	x^V
x	L. higginsi	1		1	0.08	x^V	x^V
x	L. radiata siliquoidea	1		1	0.08		x^V
x	L. ovata ventricosa	10		10	0.81	x^V	x^V
x	Arcidens confragosus	14		14	1.13	x^V	x^V
	Lasmigona complanata					x^V	x^V
	L. costata						x^V
	L. compressa						
	Alasmidonta marginata						x^V
	Simpsoniconcha ambigua						x^V
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis					x^V	x^V
x	A. grandis	12		12	0.97	x^V	x^V
x	Strophitus undulatus	4		4	0.32	x^V	x^V
25		1238	1	1239	99.97	29	40

Exhibit 82

Pool 11

Site data: Exhibits 27 and 28

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra					x^P	
x Q. quadrula	14		14	3.47	x^P	
x Q. nodulata	5		5	1.24	x^P	
x Q. pustulosa	16		16	3.96	x^P	
Tritogonia verrucosa						
Cyclonaias tuberculata						
x Fusconaia flava	25		25	6.19	x^P	
F. ebena						
x Megalonaias gigantea	29		29	7.18	x^P	
x Amblema plicata	227		227	56.19	x^P	
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
x E. dilatata	19		19	4.70		
x Obliquaria reflexa	13		13	3.22	x^P	
x Proptera alata	4		4	0.99	x^P	
x P. laevissima		1	1	0.25		
P. capax						
x Leptodea fragilis	1		1	0.25	?x^P	?x^P
L. leptodon						

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	2		2	0.50	x^P	
x	*Truncilla truncata*	6		6	1.49	x^P	
x	*T. donaciformis*	4	2	6	1.49	$?x^P$	$?x^P$
x	*Obovaria olivaria*	4		4	0.99	x^P	
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta					x^P	
	L. subrostrata						
x	*Carunculina parva*	3		3	0.74		
	Lampsilis teres						
	L. higginsi					x^P	
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	4		4	0.99	x^P	
x	*Arcidens confragosus*	4		4	0.99	x^P	
x	*Lasmigona complanata*	1		1	0.25		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	*A. imbecillis*	3		3	0.74		
x	*A. grandis*	12		12	2.97	x^P	
x	*Strophitus undulatus*	5		5	1.24	x^P	
22		401	3	404	100.03	20?	2?

Exhibit 33

Island 139

Site data: Exhibit 27

	A	J	T	%	R	F
Cumberlandia monodonta						
Quadrula metanevra						
x Q. quadrula	2		2	5.00		
x Q. nodulata	2		2	5.00		
x Q. pustulosa	3		3	7.50		
Tritogonia verrucosa						
Cyclonaias tuberculata						
x Fusconaia flava	9		9	22.50		
F. ebena						
Megalonaias gigantea						
x Amblema plicata	15		15	37.50		
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
x Obliquaria reflexa	2		2	5.00		
Proptera alata						
x P. laevissima		1	1	2.50		
P. capax						
Leptodea fragilis						
L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	*Truncilla truncata*	2		2	5.00		
x	*T. donaciformis*	2		2	5.00		
x	*Obovaria olivaria*	1		1	2.50		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	1		1	2.50		
	Strophitus undulatus						
11		39	1	40	100.00		

Exhibit 84

Hurricane Chute

Site data: Exhibit 28

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula	12		12	3.30		
x	Q. nodulata	3		3	0.82	$?x^{P}$	$?x^{P}$
x	Q. pustulosa	13		13	3.57		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	16		16	4.40	$?x^{P}$	$?x^{P}$
	F. ebena						
x	Megalonaias gigantea	29		29	7.97		
x	Amblema plicata	212		212	58.24		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
x	E. dilatata	19		19	5.22		
x	Obliquaria reflexa	11		11	3.02	$?x^{P}$	$?x^{P}$
x	Proptera alata	4		4	1.10		
	P. laevissima						
	P. capax						
x	Leptodea fragilis	1		1	0.27		
	L. leptodon						

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	2		2	0.55		
x	*Truncilla truncata*	4		4	1.10	$?x^P$	$?x^P$
x	*T. donaciformis*	2	2	4	1.10	$?x^P$	$?x^P$
x	*Obovaria olivaria*	3		3	0.82	$?x^P$	$?x^P$
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	*Carunculina parva*	3		3	0.82		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	4		4	1.10		
x	*Arcidens confragosus*	4		4	1.10		
x	*Lasmigona complanata*	1		1	0.27		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	*A. imbecillis*	3		3	0.82		
x	*A. grandis*	11		11	3.02		
x	*Strophitus undulatus*	5		5	1.37		
21		362	2	364	99.98	6?	6?

Exhibit 85

Pool 12

Site data: None

	A	J	T	[illegible]	[illegible]
[illegible] monodonta					
[illegible] metanevra					
[illegible]					
[illegible]					
[illegible]					
[illegible] verrucosa					
[illegible] tuberculata					
[illegible]					
[illegible]					
[illegible] gigantea					
[illegible]					
[illegible] cyphyus					
[illegible] cordatum					
[illegible] crassidens					
[illegible]					
[illegible] reflexa					
[illegible] alata					
P. [illegible]					
P. [illegible]					
[illegible] fragilis					
L. leptodon					

	A	J	T	%	R	H
Ellipsaria lineolata					x^P	
Truncilla truncata					x^C	
T. donaciformis					x^P	
Obovaria olivaria					x^C	
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta					x^C	
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea					x^C	
L. ovata ventricosa					x^C	
Arcidens confragosus					x^C	
Lasmigona complanata					x^C	
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis					x^C	
A. grandis					x^C	
Strophitus undulatus					x^C	
					25	

Exhibit 86

Pool 13

Site data: Exhibits 29-31

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra					x^P	x^B
x	*Q. quadrula*	27		27	5.82	x^P	x^B
x	*Q. nodulata*	5		5	1.08	x^P	x^B
x	*Q. pustulosa*	38		38	8.19	x^P	x^B
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	18		18	3.88	x^P	x^B
	F. ebena						
x	*Megalonaias gigantea*	8		8	1.72	x^P	x^B
x	*Amblema plicata*	87		87	0.19	x^P	x^B
	Plethobasus cyphyus						x^B
	Pleurobema cordatum						x^B
	Elliptio crassidens						x^B
	E. dilatata					x^P	x^B
x	*Obliquaria reflexa*	22		22	4.74	x^P	
x	*Proptera alata*	5		5	1.08	x^P	x^B
x	*P. laevissima*	4		4	0.86		
	P. capax						
x	*Leptodea fragilis*	2	30	32	6.90	x^P	x^B
	L. leptodon						x^B

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	11		11	2.37	x^P	x^E
x	*Truncilla truncata*	32		32	6.90	x^P	x^E
x	*T. donaciformis*	6	96	103	22.20		
x	*Obovaria olivaria*	42		42	9.05	x^P	
	Actinonaias carinata					x^P	x^E
	A. ellipsiformis						
x	*Ligumia recta*	1	1	2	0.43	x^P	x^E
	L. subrostrata						
x	*Carunculina parva*		1	1	0.22		x^E
	Lampsilis teres						x^E
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	10	3	13	2.80	x^P	x^E
x	*Arcidens confragosus*	6		6	1.29	x^P	x^E
x	*Lasmigona complanata*	1		1	0.22		x^E
	L. costata						x^E
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	5		5	1.08	x^P	x^E
x	*Strophitus undulatus*	2		2	0.43	x^P	x^E
21		332	132	464	31.45	20	26

		A	J	T	%	R	H
x	Ellipsaria lineolata	3		3	1.32		x B
x	Truncilla truncata	20		20	8.77		x B
x	T. donaciformis	2	68	70	30.70		
x	Obovaria olivaria	13		13	5.70		
	Actinonaias carinata						x B
	A. ellipsiformis						
x	Ligumia recta	1		1	0.44		x B
	L. subrostrata						
	Carunculina parva						x B
	Lampsilis teres						x B
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	5	2	7	3.07		x B
x	Arcidens confragosus	2		2	0.88		x B
x	Lasmigona complanata	1		1	0.44		x B
	L. costata						x B
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	5		5	2.19		x B
x	Strophitus undulatus	1		1	0.44		x B
20		148	80	228	100.01		28

Exhibit 38

Sabula

Site data: Exhibit 30

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
	Q. quadrula						
	Q. nodulata						
x	Q. pustulosa	2		2	2.86		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
	Fusconaia flava						
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	3		3	4.29		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	2		2	2.86		
	Proptera alata						
	P. laevissima						
	P. capax						
x	Leptodea fragilis		20	20	28.57		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	Truncilla truncata	3		3	4.29		
x	T. donaciformis	2	29	31	44.29		
x	Obovaria olivaria	3		3	4.29		
	Actinonaias carinata						
	A. ellipsiformis						
x	Ligumia recta		1	1	1.43		
	L. subrostrata						
x	Carunculina parva		1	1	1.43		
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	3	1	4	5.71		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
10		18	52	70	100.02		

Exhibit 39

Dark Slough

Site data: Exhibit 31

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	4		4	7.41		
x	Q. nodulata	3		3	5.56		
	Q. pustulosa						
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	2		2	3.70		
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	2		2	3.70		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	10		10	18.52		
	Proptera alata						
x	P. laevissima	1		1	1.85		
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	*Truncilla truncata*	3		3	5.56		
	T. donaciformis						
x	*Obovaria olivaria*	25		25	46.30		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	1		1	1.85		
x	*Arcidens confragosus*	3		3	5.56		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
10		54		54	100.01		

Exhibit 90

Pool 14

Site data: Exhibit 32

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra					x^P	
x	Q. quadrula	7		7	10.15	x^P	
	Q. nodulata					x^P	
x	Q. pustulosa	21		21	30.43	x^P	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						x^P
	Fusconaia flava					x^P	
	F. ebena					x^P	
x	Megalonaias gigantea	6		6	8.70	x^P	
x	Amblema plicata	19		19	27.54	x^P	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	1		1	1.45	x^P	
x	Proptera alata	2		2	2.90	x^P	
	P. laevissima					?x^P	?x^P
	P. capax						
	Leptodea fragilis					x^P	
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	6		6	3.70	x^P	
x	Truncilla truncata	3		3	4.35	x^P	
x	T. donaciformis					x^P	
	Obovaria olivaria	1		1	1.45	x^P	
	Actinonaias carinata					$?x^P$	$?x^P$
	A. ellipsiformis						
	Ligumia recta					x^P	
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres					x^P	
	L. higginsi					x^P	
	L. radiata siliquoidea					x^P	
	L. ovata ventricosa					x^P	
x	Arcidens confragosus	1		1	1.45	x^P	
	Lasmigona complanata					$?x^P$	$?x^P$
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis					x^P	
x	Strophitus undulatus	1		1	1.45	x^P	
11		69		69	100.02	26?	4?

Exhibit 91

Lock and Dam 14 Upper Approach (in part)

Site data: Exhibit 32

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	*Q. quadrula*	7		7	10.15		
	Q. nodulata						
x	*Q. pustulosa*	21		21	30.43		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
	Fusconaia flava						
	F. ebena						
x	*Megalonaias gigantea*	6		6	8.70		
x	*Amblema plicata*	19		19	27.54		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	1		1	1.45		
x	*Proptera alata*	2		2	2.90		
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	6		6	8.70		
x	Truncilla truncata	3		3	4.35		
x	T. donaciformis	1		1	1.45		
x	Obovaria olivaria	1		1	1.45		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
x	Arcidens confragosus	1		1	1.45		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
x	Strophitus undulatus	1		1	1.45		
12		69		69	100.02		

Exhibit 92

Pool 15

Site data: Exhibit 32

		A	J	T	%	R	H
x^{K}	Cumberlandia monodonta						x^{Q}
x^{K}	Quadrula metanevra					x^{P}	
x	Q. quadrula	3		3	6.98	x^{P}	
x^{K}	Q. nodulata					x^{P}	
x	Q. pustulosa	12		12	27.91	x^{P}	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						x^{Q}
	Fusconaia flava					x^{P}	
	F. ebena					x^{P}	x^{K}
x^{K}	Megalonaias gigantea					x^{P}	
x	Amblema plicata	14		14	32.56	x^{P}	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata					x^{P}	
x	Obliquaria reflexa	5		5	11.63	x^{P}	
x	Proptera alata	2		2	4.65	x^{P}	
x^{K}	P. laevissima					x^{P}	
	P. capax						
x^{T}	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	2		2	4.65	x^{P}	
x	*Truncilla truncata*	3		3	6.98	x^{P}	
x	*T. donaciformis*	1		1	2.33	x^{P}	
x^{K}	*Obovaria olivaria*					x^{P}	
x^{K}	*Actinonaias carinata*					x^{P}	
	A. ellipsiformis						
x^{K}	*Ligumia recta*					x^{P}	
	L. subrostrata						
x^{T}	*Carunculina parva*						
	Lampsilis teres					x^{K}	
	L. higginsi					x^{P}	
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	1		1	2.33	x^{P}	
	Arcidens confragosus					x^{P}	
	Lasmigona complanata						
	L. costata						x^{T}
	L. compressa					x^{P}	
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
x^{T}	*Anodonta suborbiculata*						
	A. imbecillis						
x^{K}	*A. grandis*					x^{P}	
x^{T}	*Strophitus undulatus*						x [illegible]
22		43		43	100.02	24	5

Exhibit 93

Lock and Dam 14 Upper Approach (in part)

Site data: Exhibit 32

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	*Q. quadrula*	3		3	6.98		
	Q. nodulata						
x	*Q. pustulosa*	12		12	27.91		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
	Fusconaia flava						
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	14		14	32.56		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	5		5	11.63		
x	*Proptera alata*	2		2	4.65		
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	2		2	4.65		
x	Truncilla truncata	3		3	6.98		
x	T. donaciformis	1		1	2.33		
	Obovaria olivaria						
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	1		1	2.33		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
9		43		43	100.02		

		A	J	T	%	R	H
x	Ellipsaria lineolata	6		6	3.14	x^P	x^E
x	Truncilla truncata	13		13	6.81	x^P	x^E
x	T. donaciformis		4	4	2.09	x^P	x^E
x	Obovaria olivaria	39		39	20.42	x^P	x^E
x	Actinonaias carinata	4		4	2.09	x^P	x^E
	A. ellipsiformis						
x^N	Ligumia recta					x^P	x^E
	L. subrostrata						
	Carunculina parva					x^P	
	Lampsilis teres						x^E
x^T	L. higginsi					x^P	
	L. radiata siliquoidea						
x	L. ovata ventricosa	8		8	4.19	x^P	x^E
x	Arcidens confragosus	1		1	0.52	x^P	x^Q
x	Lasmigona complanata		1	1	0.52	x^P	
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
x^N	Anodontoides ferussacianus						
	Anodonta suborbiculata						x^I
x	A. imbecillis		2	2	1.05		x^E
x	A. grandis	2		2	1.05	x^P	x
	Strophitus undulatus					x^P	x^E
23		172	19	191	99.99	27	29

Exhibit 95

Centennial Bridge

Site data: Exhibit 33

		A	J	T	%	R	H
	Cumberlandia monodonta						x
x	Quadrula metanevra	1		1	0.52		x
x	Q. quadrula	1	2	3	1.57		x
	Q. nodulata						
x	Q. pustulosa	31		31	16.23		x
	Tritogonia verrucosa						x
	Cyclonaias tuberculata						
x	Fusconaia flava	9		9	4.71		x
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	55	4	59	30.89		x
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
	Obliquaria reflexa						
x	Proptera alata	1		1	0.52		x
x	P. laevissima		2	2	1.05		x
	P. capax						
x	Leptodea fragilis	1	4	5	2.62		x
	L. leptodon						

		A	J	T	%	P.	H
x	_Ellipsaria lineolata_	6		6	3.14		x
x	_Truncilla truncata_	13		13	6.81		x
x	_T. donaciformis_		4	4	2.09		
x	_Obovaria olivaria_	39		39	20.42		x
x	_Actinonaias carinata_	4		4	2.09		
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	_L. ovata ventricosa_	8		8	4.19		x
x	_Arcidens confragosus_	1		1	0.52		
x	_Lasmigona complanata_		1	1	0.52		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	_A. imbecillis_		2	2	1.05		
x	_A. grandis_	2		2	1.05		x
	Strophitus undulatus						x[T]
18		172	19	191	99.99		15

Exhibit 96

Pool 17

Site data: Exhibit 34

		A	J	T	%	R	H
x^T	Cumberlandia monodonta					x^Z	
	Quadrula metanevra					x^Z	
x	Q. quadrula	18		18	7.11	x^Z	
x	Q. nodulata	3		3	1.19	x^Z	
x	Q. pustulosa	54		54	21.34	x^Z	
x^T	Tritogonia verrucosa					x^Z	
	Cyclonaias tuberculata						
x	Fusconaia flava	13		13	5.14	x^Z	
x^T	F. ebena					x^Z	
x^T	Megalonaias gigantea					x^Z	
x	Amblema plicata	134		134	52.96	x^Z	
x^T	Plethobasus cyphyus					x^P	
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	3		3	1.19	x^Z	
x^T	Proptera alata					x^Z	
	P. laevissima					x^Z	
	P. capax						
x	Leptodea fragilis	1		1	0.40	x^Z	
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	1		1	0.40	x^Z	
x	Truncilla truncata	7		7	2.77	x^Z	
x	T. donaciformis	1	2	3	1.19	x^Z	
x	Obovaria olivaria	10		10	3.95	x^Z	
x^T	Actinonaias carinata					x^Z	
	A. ellipsiformis						
x^T	Ligumia recta					x^P	
	L. subrostrata						
	Carunculina parva						
x^T	Lampsilis teres					x^Z	
x^T	L. higginsi						
	L. radiata siliquoidea						
x^T	L. ovata ventricosa					x^Z	
x^T	Arcidens confragosus					x^Z	
x	Lasmigona complanata	4		4	1.58	x^Z	
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	2		2	0.79	x^Z	
	Strophitus undulatus					x^Z	
25		251	2	253	100.01	27	

Exhibit 97

Bass Island

Site data: Exhibit 34

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	18		18	7.11	x^P	
x	Q. nodulata	3		3	1.19		
x	Q. pustulosa	54		54	21.34	x^P	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	13		13	5.14	x^P	
	F. ebena						
	Megalonaias gigantea					x^P	
x	Amblema plicata	134		134	52.96	x^P	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	3		3	1.19	x^P	
	Proptera alata						
	P. laevissima					x^P	
	P. capax						
x	Leptodea fragilis	1		1	0.40		
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	1		1	0.40		
x	Truncilla truncata	7		7	2.77		
x	T. donaciformis	1	2	3	1.19		
x	Obovaria olivaria	10		10	3.95	x^P	
	Actinonaias carinata					x^P	
	A. ellipsiformis						
	Ligumia recta					x^P	
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres					x^P	
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa					x^P	
	Arcidens confragosus						
x	Lasmigona complanata	4		4	1.58		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	2		2	0.79		
	Strophitus undulatus						
13		251	2	253	100.01	12	

Exhibit 98

Pool 18

Site data: Exhibits 35-36

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	Quadrula metanevra	13		13	2.90	x^P	x^E
x	Q. quadrula	34		34	7.59	x^P	x^E
x	Q. nodulata	2		2	0.45		x^E
x	Q. pustulosa	66		66	14.73	x^P	x^E
	Tritogonia verrucosa					x^P	x^E
	Cyclonaias tuberculata						
x	Fusconaia flava	19		19	4.24	x^P	x^E
	F. ebena						x^E
x	Megalonaias gigantea	7		7	1.56		x^E
x	Amblema plicata	124	7	131	29.24	x^P	x^E
	Plethobasus cyphyus					x^P	x^E
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	43		43	9.60	x^P	x^E
x	Proptera alata	4		4	0.89	x^P	x^E
x	P. laevissima	1		1	0.22	x^P	x^E
	P. capax						x^E
x	Leptodea fragilis		6	6	1.34	x^P	x^E
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	5		5	1.12	x^P	x^E
x	Truncilla truncata	18		18	4.02	x^P	x^E
x	T. donaciformis	2	70	72	16.17		x^E
x	Obovaria olivaria	22		22	4.91	x^P	x^E
	Actinonaias carinata					x^P	x^E
	A. ellipsiformis						
x	Ligumia recta	1		1	0.22	x^P	
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						x^E
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	2		2	0.45	x^P	x^E
x	Arcidens confragosus	1		1	0.22		x^E
	Lasmigona complanata						x^E
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	1		1	0.22		x^E
	Strophitus undulatus						x^E
19		365	83	443	99.99	17	24

Exhibit 99

New Boston Upper [illegible]

Site data: Exhibit 35

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	Quadrula metanevra	3		3	2.08		
x	Q. quadrula	9		9	6.25		
x	Q. nodulata	2		2	1.39		
x	Q. [illegible]	38		38	26.39		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	6		6	4.17		
	F. ebena						
	Megalonaias gigantea						
x	Amblema plicata	46		46	31.94		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	13		13	9.03		
	Proptera alata						
x	P. laevissima	1		1	0.69		
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	4		4	2.78		
x	*Truncilla truncata*	11		11	7.64		
x	*T. donaciformis*		1	1	0.69		
x	*Obovaria olivaria*	9		9	6.25		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
x	*Arcidens confragosus*	1		1	0.69		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
13		143	1	144	99.99		

Exhibit 100

Edwards River

Site data: Exhibit 3-

		A	J	T	%	R	F
	Cumberlandia monodonta						
x	*Quadrula metanevra*	10		10	3.29		
x	*Q. quadrula*	25		25	8.22		
	Q. nodulata						
x	*Q. pustulosa*	28		28	9.21		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	13		13	4.28		
	F. ebena						
x	*Megalonaias gigantea*	7		7	2.30		
x	*Amblema plicata*	78	7	85	27.96		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	30		30	9.87		
x	*Proptera alata*	4		4	1.32		
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*		6	6	1.97		
	L. leptodon						

		A	J	T	%	R	H
x	*Ellipsaria lineolata*	1		1	0.33		
x	*Truncilla truncata*	7		7	2.30		
x	*T. donaciformis*	2	69	71	23.36		
x	*Obovaria olivaria*	13		13	4.28		
	Actinonaias carinata						
	A. ellipsiformis						
x	*Ligumia recta*	1		1	0.33		
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	2		2	0.66		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	*A. grandis*	1		1	0.33		
	Strophitus undulatus						
16		222	82	304	100.01		

		A	J	T	%	R	H
x	Ellipsaria lineolata	10		10	0.35	x^G	
x	Truncilla truncata	104		104	3.63	x^G	
x	T. donaciformis	208	16	224	7.81	x^G	x^E
x	Obovaria olivaria	201		201	7.01	x^G	x^E
x	Actinonaias carinata	21		21	0.73	x^P	
	A. ellipsiformis						
x	Ligumia recta	4		4	0.14		x^E
	L. subrostrata						
x	Carunculina parva	1		1	0.03	x^G	
x	Lampsilis teres	18		18	0.63	x^G	x^E
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	30	1	31	1.08	x^G	?x^E
x	Arcidens confragosus	15		15	0.52	x^G	
x	Lasmigona complanata	1		1	0.03		?x^E
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	162		162	5.65	x^G	x^E
x	A. grandis	93		93	3.24	x^G	x^E
	Strophitus undulatus						x^E
25		2842	26	2868	99.99	21	21?

Exhibit 102

Craigel Island

Site data: Exhibit 37

		A	J	T	%	R	Y
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	25		25	6.60	x^P	
x	Q. nodulata	7		7	1.85	x^P	
x	Q. pustulosa	65		65	17.15	x^P	
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	26		26	6.86	x^P	
	F. ebena						
x	Megalonaias gigantea	8		8	2.11		
x	Amblema plicata	171		171	45.12	x^P	
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	19		19	5.01	x^P	
x	Proptera alata	3		3	0.79	x^P	
x	P. laevissima	2		2	0.53	x^P	
	P. capax						
x	Leptodea fragilis	4		4	1.05	x^P	
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	3		3	0.79		
x	Truncilla truncata	3		3	0.79	x[P]	
x	T. donaciformis	2		2	0.53		
x	Obovaria olivaria	28		28	7.39	x[P]	
x	Actinonaias carinata	3		3	0.79		
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	4		4	1.06	x[P]	
x	Arcidens confragosus	3		3	0.79	x[P]	
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	3		3	0.79	x[P]	
	Strophitus undulatus						
18		379		379	100.01	14	

Exhibit 103

The "Green Bay" Site

Site data: Exhibits 38-43

		A	J	T	%	R	H
x	<u>Cumberlandia monodonta</u>	6		6	0.24		
x	<u>Quadrula metanevra</u>	2		2	[illegible]		
x	<u>Q. quadrula</u>	300		[illegible]	[illegible]		
x	<u>Q. nodulata</u>	289		[illegible]	[illegible]		
x	<u>Q. pustulosa</u>	298		298	11.97		
	<u>Tritogonia verrucosa</u>						
	<u>Cyclonaias tuberculata</u>						
x	<u>Fusconaia flava</u>	23	1	24	0.96		
	<u>F. ebena</u>						
x	<u>Megalonaias gigantea</u>	99		99	3.98		
x	<u>Amblema plicata</u>	390	1	391	15.71		
	<u>Plethobasus cyphyus</u>						
	<u>Pleurobema cordatum</u>						
	<u>Elliptio crassidens</u>						
	<u>E. dilatata</u>						
x	<u>Obliquaria reflexa</u>	104		104	4.18		
x	<u>Proptera alata</u>	73		73	2.93		
x	<u>P. laevissima</u>	46		46	1.85		
	<u>P. capax</u>						
x	<u>Leptodea fragilis</u>	14	7	21	0.84		
	<u>L. leptodon</u>						

		A	J	T	%	R	H
x	Ellipsaria lineolata	7		7	0.28		
x	Truncilla truncata	101		101	4.06		
x	T. donaciformis	206	16	222	8.92		
x	Obovaria olivaria	173		173	6.95		
x	Actinonaias carinata	18		18	0.72		
	A. ellipsiformis						
x	Ligumia recta	4		4	0.16		
	L. subrostrata						
x	Carunculina parva	1		1	0.04		
x	Lampsilis teres	18		18	0.72		
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	26	1	27	1.08		
x	Arcidens confragosus	12		12	0.48		
x	Lasmigona complanata	1		1	0.04		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	162		162	6.51		
x	A. grandis	90		90	3.62		
	Strophitus undulatus						
25		2463	26	2489	99.98		

Exhibit 104

Turkey Island

Site data: Exhibit 39

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	25		25	10.33		
x	Q. nodulata	14		14	5.79		
x	Q. pustulosa	19		19	7.85		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	8		8	3.31		
	F. ebena						
x	Megalonaias gigantea	3		3	1.24		
x	Amblema plicata	85	1	86	35.54		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	10		10	4.13		
x	Proptera alata	1		1	0.41		
x	P. laevissima	4		4	1.65		
	P. capax						
x	Leptodea fragilis	1		1	0.41		
	L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						
x *Truncilla truncata*	3		3	1.24		
x *T. donaciformis*	13	7	20	8.26		
x *Obovaria olivaria*	9		9	3.72		
Actinonaias carinata						
A. ellipsiformis						
x *Ligumia recta*	1		1	0.41		
L. subrostrata						
Carunculina parva						
x *Lampsilis teres*	2		2	0.83		
L. higginsi						
L. radiata siliquoidea						
x *L. ovata ventricosa*	2		2	0.83		
x *Arcidens confragosus*	1		1	0.41		
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
x *A. imbecillis*	23		23	0.50		
x *A. grandis*	10		10	4.13		
Strophitus undulatus						
19	234	8	242	99.99		

Exhibit 105

Thompson Island

Site data: Exhibit 40

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	59		59	11.07		
x	Q. nodulata	88		88	16.51		
x	Q. pustulosa	68		68	12.76		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	5	1	6	1.13		
	F. ebena						
x	Megalonaias gigantea	68		68	12.76		
x	Amblema plicata	53		53	9.94		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	24		24	4.50		
x	Proptera alata	6		6	1.13		
x	P. laevissima	3		3	0.56		
	P. capax						
x	Leptodea fragilis	2	1	3	0.56		
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	2		2	0.38		
x	Truncilla truncata	29		29	5.44		
x	T. donaciformis	59	6	65	12.20		
x	Obovaria olivaria	30		30	5.63		
	Actinonaias carinata						
	A. ellipsiformis						
x	Ligumia recta	1		1	0.19		
	L. subrostrata						
	Carunculina parva						
x	Lampsilis teres	2		2	0.38		
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	5	1	6	1.13		
x	Arcidens confragosus	4		4	0.75		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	15		15	2.81		
x	A. grandis	1		1	0.19		
	Strophitus undulatus						
20		524	9	533	100.02		

Exhibit 106

Dallas Island

Site data: Exhibit 41

		A	J	T	%	R	H
x	Cumberlandia monodonta	4		4	0.42		
x	Quadrula metanevra	2		[illegible]	0.21		
x	Q. quadrula	132		132	13.79		
x	Q. nodulata	140		140	14.63		
x	Q. pustulosa	186		186	19.44		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	9		9	0.94		
	F. ebena						
x	Megalonaias gigantea	20		20	2.09		
x	Amblema plicata	75		75	7.84		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	33		33	3.45		
x	Proptera alata	30		30	3.13		
	P. laevissima						
	P. capax						
x	Leptodea fragilis	9	4	13	1.36		
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	5		5	0.52		
x	Truncilla truncata	57		57	5.96		
x	T. donaciformis	77	2	79	8.25		
x	Obovaria olivaria	112		112	11.70		
x	Actinonaias carinata	17		17	1.78		
	A. ellipsiformis						
x	Ligumia recta	2		2	0.21		
	L. subrostrata						
	Carunculina parva						
x	Lampsilis teres	4		4	0.42		
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	15		15	1.57		
x	Arcidens confragosus	5		5	0.52		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	9		9	0.94		
x	A. grandis	8		8	0.84		
	Strophitus undulatus						
22		951	6	957	100.01		

Exhibit 107

Pontoosuc

Site data: Exhibit 42

		A	J	T	%	R	H
x	Cumberlandia monodonta	2		2	0.97		
	Quadrula metanevra						
x	Q. quadrula	54		54	26.21		
x	Q. nodulata	26		26	12.62		
x	Q. pustulosa	10		10	4.85		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	1		1	0.49		
	F. ebena						
x	Megalonaias gigantea	6		6	2.91		
x	Amblema plicata	8		8	3.88		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	10		10	4.85		
x	Proptera alata	20		20	9.71		
x	P. laevissima	1		1	0.49		
	P. capax						
x	Leptodea fragilis	1	2	3	1.46		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	Truncilla truncata	11		11	5.34		
x	T. donaciformis	26		26	12.62		
x	Obovaria olivaria	6		6	2.91		
x	Actinonaias carinata	1		1	0.49		
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
x	Lampsilis teres	5		5	2.43		
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	3		3	1.46		
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	3		3	1.46		
x	A. grandis	10		10	4.85		
	Strophitus undulatus						
19		204	2	206	100		

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FRESH-WATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE) OF THE UPPE--ETC(U)
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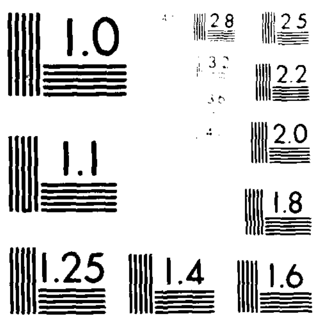

MICROCOPY RESOLUTION TEST CHART

		A	J	T	%	R	H
	Ellipsaria lineolata						
x	Truncilla truncata	1		1	0.18		
x	T. donaciformis	31	1	32	5.81		
x	Obovaria olivaria	16		16	2.90		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
x	Carunculina parva	1		1	0.18		
x	Lampsilis teres	5		5	0.91		
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	1		1	0.18		
x	Arcidens confragosus	2		2	0.36		
x	Lasmigona complanata	1		1	0.18		
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
x	A. imbecillis	112		112	20.33		
x	A. grandis	61		61	11.07		
	Strophitus undulatus						
19		550	1	551	99.98		

Exhibit 109

Pool 20

Site data: Exhibits 44-45

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	*Quadrula metanevra*	1		1	0.94	?x^P	?x^P
x	*Q. quadrula*	27		27	25.47	x^P	?x^E
x	*Q. nodulata*	1		1	0.94	x^P	?x^E
x	*Q. pustulosa*	19		19	17.92	x^P	?x^E
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	12		12	11.32	x^P	?x^E
	F. ebena					x^P	
x	*Megalonaias gigantea*	1		1	0.94		?x^E
x	*Amblema plicata*	26		26	24.53	x^P	?x^E
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	5		5	4.72		?x^E
	Proptera alata						?x^E
x	*P. laevissima*	2		2	1.89		?x^E
	P. capax						
	Leptodea fragilis						?x^E
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	2		2	1.89		
	Truncilla truncata					x^P	
	T. donaciformis					x^P	?x^E
x	Obovaria olivaria	8		8	7.55	x^P	
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta					x^P	?x^E
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres					x^P	?x^E
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa					x^P	x^E
x	Arcidens confragosus	1		1	0.94		
	Lasmigona complanata					x^P	?x^E
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata					x^P	
	A. imbecillis						?x^E
x	A. grandis	1		1	0.94		?x^E
	Strophitus undulatus						
13		106		106	99.99	14?	18?

Exhibit 110

Fox Island

Site data: Exhibit 44

		A	J	T	%	R	H
	Cumberlandia monodonta						
	Quadrula metanevra						
x	Q. quadrula	12		12	22.64		
	Q. nodulata						
x	Q. pustulosa	10		10	18.87		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	Fusconaia flava	6		6	11.32		
	F. ebena						
x	Megalonaias gigantea	1		1	1.89		
x	Amblema plicata	17		17	32.08		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	1		1	1.89		
	Proptera alata						
	P. laevissima						
	P. capax						
	Leptodea fragilis						
	L. leptodon						

		A	J	T	%	R	H
x	Ellipsaria lineolata	2		2	3.77		
	Truncilla truncata						
	T. donaciformis						
x	Obovaria olivaria	2		2	3.77		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
x	Arcidens confragosus	1		1	1.89		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
x	A. grandis	1		1	1.89		
	Strophitus undulatus						
10		53		53	100.01		

Exhibit 111

Buzzard Island

Site data: Exhibit 45

	A	J	T	%	R	H
Cumberlandia monodonta						
x Quadrula metanevra	1		1	1.89		
x Q. quadrula	15		15	28.30	x^P	
x Q. nodulata	1		1	1.89	x^P	
x Q. pustulosa	9		9	16.98	x^P	
Tritogonia verrucosa						
Cyclonaias tuberculata						
x Fusconaia flava	6		6	11.32		
F. ebena						
Megalonaias gigantea						
x Amblema plicata	9		9	16.98	x^P	
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
x Obliquaria reflexa	4		4	7.55		
Proptera alata						
x P. laevissima	2		2	3.77		
P. capax						
Leptodea fragilis					x^P	
L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
	T. donaciformis					?x^P	
x	*Obovaria olivaria*	6		6	11.32	x^P	
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres					x^P	
	L. higginsi						
	L. radiata siliquoidea						
	L. ovata ventricosa						
	Arcidens confragosus						
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
9		53		53	100.00	8	

Exhibit 112

Pool 21

Site data: Exhibit 46

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	Quadrula metanevra	1		1	1.45	x^P	x^E
x	Q. quadrula	10		10	14.49	x^P	x^E
x	Q. nodulata	1		1	1.45	x^P	x^E
x	Q. pustulosa	19		19	27.54	x^P	x^E
	Tritogonia verrucosa						x^E
	Cyclonaias tuberculata						
x	Fusconaia flava	12		12	17.34	x^P	x^E
	F. ebena					x^P	x^E
	Megalonaias gigantea						
x	Amblema plicata	19		19	27.54	x^P	x^E
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	Obliquaria reflexa	3		3	4.35	x^P	x^E
	Proptera alata					$?x^P$	$?x^P$
	P. laevissima						x^E
	P. capax						x^E
x	Leptodea fragilis	1		1	1.45		x^E
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata					x^P	x^E
	Truncilla truncata					x^P	
	T. donaciformis					x^P	x^E
x	Obovaria olivaria	1		1	1.45	x^P	x^E
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						x^E
	L. higginsi						
	L. radiata siliquoidea						
x	L. ovata ventricosa	1		1	1.45	$?x^P$	$?x^P$
x	Arcidens confragosus	1		1	1.45		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
11		69		69	100.01	14?	18?

Exhibit 113

Howards Island

Site data: Exhibit 46

		A	J	T	%	R	H
	Cumberlandia monodonta						
x	*Quadrula metanevra*	1		1	1.45		
x	*Q. quadrula*	10		10	14.49		
x	*Q. nodulata*	1		1	1.45		
x	*Q. pustulosa*	19		19	27.54		
	Tritogonia verrucosa						
	Cyclonaias tuberculata						
x	*Fusconaia flava*	12		12	17.39		
	F. ebena						
	Megalonaias gigantea						
x	*Amblema plicata*	19		19	27.54		
	Plethobasus cyphyus						
	Pleurobema cordatum						
	Elliptio crassidens						
	E. dilatata						
x	*Obliquaria reflexa*	3		3	4.35		
	Proptera alata						
	P. laevissima						
	P. capax						
x	*Leptodea fragilis*	1		1	1.45		
	L. leptodon						

		A	J	T	%	R	H
	Ellipsaria lineolata						
	Truncilla truncata						
	T. donaciformis						
x	*Obovaria olivaria*	1		1	1.45		
	Actinonaias carinata						
	A. ellipsiformis						
	Ligumia recta						
	L. subrostrata						
	Carunculina parva						
	Lampsilis teres						
	L. higginsi						
	L. radiata siliquoidea						
x	*L. ovata ventricosa*	1		1	1.45		
x	*Arcidens confragosus*	1		1	1.45		
	Lasmigona complanata						
	L. costata						
	L. compressa						
	Alasmidonta marginata						
	Simpsoniconcha ambigua						
	Anodontoides ferussacianus						
	Anodonta suborbiculata						
	A. imbecillis						
	A. grandis						
	Strophitus undulatus						
11		69		69	100.01		

Exhibit 114

Pool 22

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra					x^P	
Q. quadrula					x^P	x^E
Q. nodulata					x^P	x^E
Q. pustulosa					x^P	
Tritogonia verrucosa						x^E
Cyclonaias tuberculata						
Fusconaia flava					x^P	x^E
F. ebena					x^P	x^E
Megalonaias gigantea					x^P	x^E
Amblema plicata					x^P	x^E
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa					x^P	x^E
Proptera alata					x^P	
P. laevissima						x^E
P. capax						x^E
Leptodea fragilis					x^P	x^E
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata					x^P	
Truncilla truncata						
T. donaciformis						x^E
Obovaria olivaria					x^P	x^E
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						x^E
L. subrostrata						
Carunculina parva						
Lampsilis teres						x^E
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa					x^P	
Arcidens confragosus					x^P	
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis					x^P	
Strophitus undulatus						
					16	15

Exhibit 115

Pool 24

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta					x^{O}	
Quadrula metanevra					x^{O}	$?x^{E}$
Q. quadrula					x^{O}	$?x^{E}$
Q. nodulata					x^{O}	$?x^{E}$
Q. pustulosa					x^{O}	$?x^{E}$
Tritogonia verrucosa						$?x^{E}$
Cyclonaias tuberculata						
Fusconaia flava					x^{O}	$?x^{E}$
F. ebena					x^{O}	$?x^{E}$
Megalonaias gigantea					x^{O}	$?x^{E}$
Amblema plicata					x^{O}	$?x^{E}$
Plethobasus cyphyus						$?x^{E}$
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa					x^{O}	$?x^{E}$
Proptera alata					x^{O}	
P. laevissima						
P. capax					x^{P}	x^{O}
Leptodea fragilis					x^{O}	$?x^{E}$
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata					x^{O}	$?x^{E}$
Truncilla truncata					x^{O}	$?x^{E}$
T. donaciformis					x^{O}	$?x^{E}$
Obovaria olivaria					x^{O}	$?x^{E}$
Actinonaias carinata						$?x^{E}$
A. ellipsiformis						
Ligumia recta					x^{P}	$?x^{E}$
L. subrostrata						
Carunculina parva						
Lampsilis teres					x^{O}	$?x^{E}$
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa					x^{O}	
Arcidens confragosus						
Lasmigona complanata						$?x^{E}$
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis					x^{O}	$?x^{E}$
A. grandis					x^{O}	
Strophitus undulatus					x^{O}	
					23	22 ?

Exhibit 116

Pool 25

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						?x[E]
Q. quadrula						?x[E]
Q. nodulata						?x[E]
Q. pustulosa						?x[E]
Tritogonia verrucosa						?x[E]
Cyclonaias tuberculata						
Fusconaia flava						?x[E]
F. ebena						?x[E]
Megalonaias gigantea						?x[E]
Amblema plicata						?x[E]
Plethobasus cyphyus						?x[E]
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						?x[E]
Proptera alata						
P. laevissima						
P. capax						?x[E]
Leptodea fragilis						?x[E]
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						?x^E
Truncilla truncata						?x^E
T. donaciformis						?x^E
Obovaria olivaria						?x^E
Actinonaias carinata						?x^E
A. ellipsiformis						
Ligumia recta						?x^E
L. subrostrata						
Carunculina parva						
Lampsilis teres						?x^E
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						?x^E
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						?x^E
A. grandis						
Strophitus undulatus						
						22 ?

Exhibit 117

Pool 26

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula					x^P	x^E
Q. nodulata					x^P	x^E
Q. pustulosa					x^P	x^E
Tritogonia verrucosa						x^E
Cyclonaias tuberculata						
Fusconaia flava					x^P	x^E
F. ebena						
Megalonaias gigantea					x^P	x^E
Amblema plicata					x^P	x^E
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa					x^P	x^E
Proptera alata					x^P	x^E
P. laevissima					x^P	x^E
P. capax						x^E
Leptodea fragilis					x^P	x^E
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata					x^P	
Truncilla truncata					x^P	x^E
T. donaciformis					x^P	x^E
Obovaria olivaria					x^P	x^E
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres					x^P	x^E
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						x^E
Lasmigona complanata						x^E
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						x^E
A. grandis					x^P	x^E
Strophitus undulatus						
					16	20

Exhibit 118

Pool 27

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula						
Q. nodulata						
Q. pustulosa						
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea						
Amblema plicata						
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa						
Proptera alata						
P. laevissima						
P. capax						
Leptodea fragilis						
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata						
Truncilla truncata						
T. donaciformis						
Obovaria olivaria						
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva						
Lampsilis teres						
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus						
Lasmigona complanata						
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis						
Strophitus undulatus						

Exhibit 119

Below Pool 27

Site data: None

	A	J	T	%	R	H
Cumberlandia monodonta						
Quadrula metanevra						
Q. quadrula					x^0	
Q. nodulata						
Q. pustulosa					x^0	
Tritogonia verrucosa						
Cyclonaias tuberculata						
Fusconaia flava						
F. ebena						
Megalonaias gigantea					x^0	
Amblema plicata					x^0	
Plethobasus cyphyus						
Pleurobema cordatum						
Elliptio crassidens						
E. dilatata						
Obliquaria reflexa					x^0	
Proptera alata					x^0	
P. laevissima					x^0	
P. capax						
Leptodea fragilis					x^0	
L. leptodon						

	A	J	T	%	R	H
Ellipsaria lineolata					x^{O}	
Truncilla truncata					x^{O}	
T. donaciformis					x^{O}	
Obovaria olivaria					x^{O}	
Actinonaias carinata						
A. ellipsiformis						
Ligumia recta						
L. subrostrata						
Carunculina parva					x^{P}	
Lampsilis teres					x^{O}	
L. higginsi						
L. radiata siliquoidea						
L. ovata ventricosa						
Arcidens confragosus					x^{O}	
Lasmigona complanata					x^{O}	
L. costata						
L. compressa						
Alasmidonta marginata						
Simpsoniconcha ambigua						
Anodontoides ferussacianus						
Anodonta suborbiculata						
A. imbecillis						
A. grandis					x^{P}	
Strophitus undulatus						

Appendix D

Exhibit 120

Systematic List of Fishes with Their Vernacular Names

Exhibit 121

Mussel-Host Correlations

Exhibit 120

Systematic List of Fishes with Their Vernacular Names

The following phylogenetic list provides the classification and standardized Latin and common names according to Bailey et al. (1970) of fishes that have been identified and/or implicated as glochidial hosts of Upper Mississippi River fresh-water mussels.

Phylum CHORDATA
Subphylum Vertebrata
Class Agnatha
Order Petromyzontiformes
Family Petromyzontidae
Petromyzon marinus Linnaeus, Sea Lamprey
Class Osteichthyes
Order Acipenseriformes
Family Acipenseridae
Scaphirhynchus platorhynchus (Rafinesque), Shovelnose Sturgeon
Order Semionotiformes
Family Lepisosteidae
Lepisosteus osseus (Linnaeus), Longnose Gar
L. platostomus Rafinesque, Shortnose Gar
L. spatula Lacépède, Alligator Gar
Order Amiiformes
Family Amiidae
Amia calva Linnaeus, Bowfin
Order Anguilliformes
Family Anguillidae
Anguilla rostrata (Lesueur), American Eel
Order Clupeiformes
Family Clupeidae
Alosa chrysochloris (Rafinesque), Skipjack Herring
Dorosoma cepedianum (Lesueur), Gizzard Shad
Order Salmoniformes
Family Esocidae
Esox lucius Linnaeus, Northern Pike
Order Cypriniformes
Family Cyprinidae
Cyprinus carpio Linnaeus, Carp
Hybognathus hankinsoni Hobbs, Brassy Minnow
Nocomis biguttatus (Kirtland), Horneyhead Chub
Notemigonus chrysoleucas (Mitchill), Golden Shiner
Notropis ardens (Cope), Rosefin Shiner
N. cornutus (Mitchill), Common Shiner
N. heterolepis Eigenmann and Eigenmann, Blacknose Shiner
Phoxinus eos (Cope), Northern Redbelly Dace

Pimephales notatus (Rafinesque), Bluntnose Minnow
P. promelas Rafinesque, Fathead Minnow
Rhinichthys atratulus (Hermann), Blacknose Dace
Semotilus atromaculatus (Mitchill), Creek Chub
Family Catostomidae
Carpiodes velifer (Rafinesque), Highfin Carpsucker
Catostomus commersoni (Lacépède), White Sucker
Hypentelium nigricans (Lesueur), Northern Hog Sucker
Moxostoma macrolepidotum (Lesueur), Shorthead Redhorse
Order Siluriformes
Family Ictaluridae
Ictalurus melas (Rafinesque), Black Bullhead
I. natalis (Lesueur), Yellow Bullhead
I. nebulosus (Lesueur), Brown Bullhead
I. punctatus (Rafinesque), Channel Catfish
Noturus gyrinus (Mitchill), Tadpole Madtom
Pylodictis olivaris (Rafinesque), Flathead Catfish
Order Atheriniformes
Family Cyprinodontidae
Fundulus zebrinus Jordan and Gilbert, Rio Grande Killifish
Order Gasterosteiformes
Family Gasterosteidae
Culaea inconstans (Kirtland), Brook Stickleback
Order Perciformes
Family Percichthyidae
Morone chrysops (Rafinesque), White Bass
Family Centrarchidae
Ambloplites rupestris (Rafinesque), Rock Bass
Lepomis cyanellus Rafinesque, Green Sunfish
L. gibbosus (Linnaeus), Pumpkinseed
L. gulosus (Cuvier), Warmouth
L. humilis (Girard), Orangespotted Sunfish
L. macrochirus Rafinesque, Bluegill
L. megalotis (Rafinesque), Longear Sunfish
Micropterus dolomieui Lacépède, Smallmouth Bass
M. salmoides (Lacépède), Largemouth Bass
Pomoxis annularis Rafinesque, White Crappie
P. nigromaculatus (Lesueur), Black Crappie
Family Percidae
Etheostoma exile (Girard), Iowa Darter
E. nigrum Rafinesque, Johnny Darter
Perca flavescens (Mitchill), Yellow Perch
Stizostedion canadense (Smith), Sauger
S. v. vitreum (Mitchill), Walleye
Family Sciaenidae
Aplodinotus grunniens Rafinesque, Freshwater Drum
Family Cottidae
Cottus bairdi Girard, Mottled Sculpin

Exhibit 121

Mussel-Host Correlations

The format and content of the lists below are adaptations of those in Fuller's (1974b) tabulation of Nearctic mussel-host relationships. Certain corrections of that compilation have been made, and it has been augmented by information that has come to the Principal Investigator's attention since 1974. Chief among these additions is Kakonge's (1972) work, which provides an especially large number of new records involving glochidiosis by *Anodontoides ferussacianus*. Other "new" work was done by Tedla and Fernando (1969a, 1969b, 1970), but Wiles' (1975) valuable study is disappointingly irrelevant to Upper Mississippi River naiades. Moles' (1977) equally significant investigations, also, are at least geographically extralimital to this report. Apparently, opportunities for discovering previously overlooked knowledge of host-parasite relationships among Nearctic naiades are nearly exhausted.

With few exceptions, the records below are the work of the Fairport group, each of whom personally had access to the same rich body of information. It is often impossible to ascertain who was first to discover a given host-parasite correlation and whether subsequent mention of it by another writer is merely the use of previously published data or the novel announcement of an independent discovery that confirms the original one. Moreover, fifty years ago, when one could approach the small amount of literature in a Baconian fashion impossible today, consistent and precise citation of sources was less common. For these reasons, the lists of references below are usually redundant, in fairness to all concerned and in order to offer the modern student an amplified opportunity to review most, perhaps all, of the available information. The practice of referring to Baker (1928) or, increasingly, to Fuller (1974b) or even to Coker et al. (1921) usually means that a writer has missed the primary source and with it much other relevant information.

The records given below do not include certain relevant ones that do not fit the present tabular format. First, J.P. E. Morrison (*in* Clarke and Berg, 1959) and Read and Oliver (1953) gave unidentified *Notropis* (Cyprinidae) as hosts for *Anodonta grandis*. Second, Shira (1913) found on Blackstripe Topminnow, *Fundulus notatus* (Rafinesque) (Cyprinodontidae), a glochidium resembling that of *Proptera capax*. Third, the Mudpuppy, *Necturus maculosus* Rafinesque, an amphibian, is host to *Simpsoniconcha ambigua* (Howard, 1914c, 1915, 1951).

Amblema plicata

Lepisosteus platostomus	Coker et al. (1921) Howard and Anson (1922)
Esox lucius	Coker et al. (1921) C. B. Wilson (1916)
Carpiodes velifer	Howard (1914c)
Ictalurus punctatus	Howard (1914c)
Pylodictis olivaris	Howard (1914c)
Morone chrysops	Coker et al. (1921) C. B. Wilson (1916)
Ambloplites rupestris	Stein (1968)
Lepomis cyanellus	Stein (1968)
L. gibbosus	Coker et al. (1921) Stein (1968)
L. gulosus	Coker et al. (1921) Howard (1914c) Pearse (1924) Stein (1968)
L. macrochirus	Howard (1914c) Stein (1968)
Micropterus salmoides	Coker et al. (1921) Howard (1914c) Lefevre and Curtis (1912) Reuling (1919)
Pomoxis annularis	Coker et al. (1921) Howard (1914c) Surber (1913) C. B. Wilson (1916)
P. nigromaculatus	Coker et al. (1921) Howard (1914c)
Stizostedion canadense	Coker et al. (1921) Howard (1914c) Surber (1913) C. B. Wilson (1916)

Fusconaia ebena

Alosa chrysochloris	Coker (1919) Coker et al. (1921) Howard (1914c, 1917) Surber (1913) C. B. Wilson (1916)
Lepomis cyanellus	Coker et al. (1921)
Micropterus salmoides	Howard (1914c)
Pomoxis annularis	Howard (1914c)
P. nigromaculatus	Howard (1914c)

Fusconaia flava

Lepomis macrochirus	Howard (1914c)
Pomoxis annularis	Coker et al. (1921) Howard (1914c) C. B. Wilson (1916)
P. nigromaculatus	Surber (1913) C. B. Wilson (1916)

Megalonaias gigantea

Amia calva	Howard (1914c)
Anguilla rostrata	Coker et al. (1921) Surber (1915) C. B. Wilson (1916)
Alosa chrysochloris	Coker et al. (1921) C. B. Wilson (1916)
Dorosoma cepedianum	Coker et al. (1921) Howard (1914c)
Carpiodes velifer	Howard (1914c)
Ictalurus melas	Coker et al. (1921) Howard (1914c)
I. nebulosus	Coker et al. (1921)
I. punctatus	Coker et al. (1921) Howard (1914c)

Pylodictis olivaris	Coker et al. (1921) Howard (1914c)
Morone chrysops	Coker et al. (1921) Howard (1914c) C. B. Wilson (1916)
Lepomis macrochirus	Coker et al. (1921) Howard (1914c)
Micropterus salmoides	Howard (1914c)
Pomoxis annularis	Coker et al. (1921)
P. nigromaculatus	Coker et al. (1921) Howard (1914c)
Stizostedion canadense	Howard (1914c)
Aplodinotus grunniens	Coker et al. (1921) Howard (1914c) Surber (1913, 1915) C. B. Wilson (1916)

Quadrula metanevra

Lepomis cyanellus	Surber (1913) C. B. Wilson (1916)
L. macrochirus	Coker et al. (1921) Howard (1914c) Surber (1913)
Stizostedion canadense	Coker et al. (1921) Howard (1914c)

Quadrula nodulata

Ictalurus punctatus	Coker et al. (1921) C. B. Wilson (1916)
Pylodictis olivaris	Coker et al. (1921)
Lepomis macrochirus	Howard (1914c)
Micropterus salmoides	Howard (1914c)

Pomoxis annularis	Coker et al. (1921) Surber (1913) C. B. Wilson (1916)
P. nigromaculatus	Howard (1914c)

Quadrula pustulosa

Scaphirhynchus platorhynchus	Coker et al. (1921)
Ictalurus melas	Coker et al. (1921) Howard (1913, 1914c)
I. nebulosus	Coker et al. (1921) Howard (1914c)
I. punctatus	Coker et al. (1921) Howard (1913, 1914c)
Pylodictis olivaris	Coker et al. (1921) Howard (1913, 1914c) C. B. Wilson (1916)
Pomoxis annularis	Coker et al. (1921) Surber (1913) C. B. Wilson (1916)

Quadrula quadrula

Pylodictis olivaris	Howard and Anson (1922)

Elliptio crassidens

Alosa chrysochloris	Howard (1914c, 1917)

Elliptio dilatata

Dorosoma cepedianum	C. B. Wilson (1916)
Pylodictis olivaris	Howard (1914c)
Pomoxis annularis	Howard (1914c) C. B. Wilson (1916)
P. nigromaculatus	Howard (1914c)
Perca flavescens	Howard (1914c)

Plethobasus cyphyus	
Stizostedion canadense	Surber (1913) C. B. Wilson (1916)
Pleurobema cordatum	
Notropis ardens	Yokley (1972)
Lepomis macrochirus	Coker et al. (1921)
Alasmidonta marginata	
Catostomus commersoni	Howard and Anson (1922)
Hypentelium nigricans	Howard and Anson (1922)
Moxostoma macrolepidotum	Howard and Anson (1922)
Ambloplites rupestris	Howard and Anson (1922)
Lepomis gulosus	Howard and Anson (1922)
Anodonta grandis	
Lepisosteus spatula	Coker et al. (1921) C. B. Wilson (1916)
Alosa chrysochloris	Surber (1913) C. B. Wilson (1916)
Dorosoma cepedianum	C. B. Wilson (1916)
Cyprinus carpio	Lefevre and Curtis (1910b) J. P. E. Morrison (*in* Clarke and Berg, 1959)
Notemigonus chrysoleucas	Lefevre and Curtis (1910b) Read and Oliver (1953)
Notropis cornutus	Kakonge (1972)
Semotilus atromaculatus	Kakonge (1972)
Catostomus commersoni	Kakonge (1972)
Ictalurus natalis	C. B. Wilson (1916)

Culaea inconstans	J. P. E. Morrison (*in* Clarke and Berg, 1959)
Morone chrysops	C. B. Wilson (1916)
Ambloplites rupestris	Lefevre and Curtis (1910b) Tucker (1928) C. B. Wilson (1916)
Lepomis cyanellus	Tucker (1928)
L. macrochirus	Lefevre and Curtis (1910b) J. P. E. Morrison (*in* Clarke and Berg, 1959) Penn (1939) C. B. Wilson (1916)
L. megalotis	Penn (1939)
Micropterus salmoides	J. P. E. Morrison (*in* Clarke and Berg, 1959) Penn (1939) C. B. Wilson (1916)
Pomoxis annularis	Lefevre and Curtis (1910b) J. P. E. Morrison (*in* Clarke and Berg, 1959) C. B. Wilson (1916)
P. nigromaculatus	C. B. Wilson (1916)
Etheostoma exile	J. P. E. Morrison (*in* Clarke and Berg, 1959)
E. nigrum	J. P. E. Morrison (*in* Clarke and Berg, 1959)
Perca flavescens	Lefevre and Curtis (1910b)
Aplodinotus grunniens	C. B. Wilson (1916)

Anodonta imbecillis

Semotilus atromaculatus	Clarke and Berg (1959)
Lepomis cyanellus	Tucker (1927)

Anodontoides ferussacianus	
Petromyzon marinus	K. A. Wilson and Ronald (1967)
Notropis cornutus	Kakonge (1972)
N. heterolepis	Kakonge (1972)
Pimephales notatus	Kakonge (1972)
P. promelas	Kakonge (1972)
Catostomus commersoni	Kakonge (1972)
Culaea inconstans	Kakonge (1972)
Etheostoma exile	Kakonge (1972)
Cottus bairdi	J. P. E. Morrison (*in* Clarke and Berg, 1959)
Arcidens confragosus	
Anguilla rostrata	C. B. Wilson (1916)
Dorosoma cepedianum	Surber (1913) C. B. Wilson (1916)
Ambloplites rupestris	Surber (1913)
Pomoxis annularis	Surber (1913) C. B. Wilson (1916)
Aplodinotus grunniens	C. B. Wilson (1916)
Lasmigona complanata	
Cyprinus carpio	Lefevre and Curtis (1910b)
Lepomis cyanellus	Lefevre and Curtis (1912)
Micropterus salmoides	Lefevre and Curtis (1910b)
Pomoxis annularis	Lefevre and Curtis (1912)

Lasmigona costata	
Cyprinus carpio	Lefevre and Curtis (1910b)
Strophitus undulatus	
Semotilus atromaculatus	A. D. Howard (R. L. Barney *in* Baker, 1928)
Fundulus zebrinus	Ellis and Keim (1918)
Lepomis cyanellus	Ellis and Keim (1918)
Micropterus salmoides	A. D. Howard (R. L. Barney *in* Baker, 1928)
Actinonaias carinata	
Anguilla rostrata	Coker et al. (1921)
Noturus gyrinus	Coker et al. (1921)
Morone chrysops	Coker et al. (1921) Surber (1913) C. B. Wilson (1916)
Ambloplites rupestris	Lefevre and Curtis (1910b)
Lepomis cyanellus	Coker et al. (1921) Lefevre and Curtis (1912) C. B. Wilson (1916)
L. macrochirus	Coker et al. (1921) C. B. Wilson (1916)
Micropterus dolomieui	Coker et al. (1921) Howard and Anson (1922)
M. salmoides	Coker et al. (1921) Lefevre and Curtis (1910b, 1912) Reuling (1919) C. B. Wilson (1916)
Pomoxis annularis	Coker et al. (1921) Lefevre and Curtis (1912) C. B. Wilson (1916)
P. nigromaculatus	Coker et al. (1921)

Perca flavescens	Coker et al. (1921)
	Lefevre and Curtis (1910b)
Stizostedion canadense	Coker et al. (1921)
	Pearse (1924)
Carunculina parva	
Lepomis cyanellus	Mermilliod (1973)
L. gulosus	C. B. Wilson (1916)
L. humilis	Mermilliod (1973)
L. macrochirus	Mermilliod (1973)
Pomoxis annularis	Mermilliod (1973)
Lampsilis higginsi	
Stizostedion canadense	Coker et al. (1921)
	Surber (1913)
	C. B. Wilson (1916)
Aplodinotus grunniens	Coker et al. (1921)
	C. B. Wilson (1916)
Lampsilis ovata ventricosa	
Lepomis macrochirus	Coker et al.(1921)
Micropterus dolomieui	Coker et al. (1921)
M. salmoides	Coker et al. (1921)
	Lefevre and Curtis (1912)
	Reuling (1919)
Pomoxis annularis	Coker et al. (1921)
	C. B. Wilson (1916)
Perca flavescens	Coker et al. (1921)
Stizostedion canadense	Coker et al. (1921)
	C. B. Wilson (1916)

Lampsilis radiata siliquoidea

Notropis cornutus	Kakonge (1972)
Catostomus commersoni	Kakonge (1972)
Noturus gyrinus	Coker et al. (1921)
Morone chrysops	Coker et al. (1921) Corwin (1920)
Ambloplites rupestris	Evermann and Clark (1918, 1920)
Lepomis macrochirus	Coker et al. (1921) Evermann and Clark (1918, 1920) Howard (1922)
Micropterus dolomieui	Coker et al.(1921) Corwin (1920) Tedla and Fernando (1969b)
M. salmoides	Arey (1923) Coker et al. (1921) Howard (1914b, 1922) Reuling (1919) Tedla and Fernando (1969b)
Pomoxis annularis	Coker et al. (1921) Howard (1922)
P. nigromaculatus	Coker et al. (1921) Howard (1922) Tedla and Fernando (1969b)
Perca flavescens	Coker et al. (1921) Corwin (1920) Kakonge (1972) Pearse (1924)
Stizostedion canadense	Coker et al. (1921) Corwin (1920)
S. v. vitreum	Coker et al. (1921) Corwin (1920, 1921)

Lampsilis teres

Scaphirhynchus platorhynchus	Coker et al. (1921) Surber (1913) C. B. Wilson (1916)
Lepisosteus osseus	Coker et al. (1921) Jones (1950) Reuling (1919) C. B. Wilson (1916)
L. platostomus	Coker et al. (1921) Howard (1914a) Howard and Anson (1922) Jones (1950) Reuling (1919) C. B. Wilson (1916)
Lepomis cyanellus	Coker et al. (1921) Surber (1913)
L. gulosus	C. B. Wilson (1916)
L. humilis	Coker et al. (1921) Surber (1913)
Micropterus salmoides	Coker (1919) Coker et al. (1921) C. B. Wilson (1916)
Pomoxis annularis	Coker et al. (1921) Surber (1913) C. B. Wilson (1916)
P. nigromaculatus	Coker et al. (1921) Surber (1913)

Leptodea fragilis

Aplodinotus grunniens	Howard (1913) C. B. Wilson (1916)

Ligumia recta

Anguilla rostrata	Coker et al. (1921)

Lepomis macrochirus	Clarke and Berg (1959) Coker et al. (1921) Lefevre and Curtis (1912) C. B. Wilson (1916)
Micropterus salmoides	Lefevre and Curtis (1912)
Pomoxis annularis	Clarke and Berg (1959) Coker et al. (1921) Lefevre and Curtis (1912) C. B. Wilson (1916)
Stizostedion canadense	Pearse (1924)
Ligumia subrostrata	
Lepomis cyanellus	Lefevre and Curtis (1912)
L. humilis	Lefevre and Curtis (1912)
L. macrochirus	Lefevre and Curtis (1912)
Micropterus salmoides	Lefevre and Curtis (1912)
Obovaria olivaria	
Scaphirhynchus platorhynchus	Coker et al. (1921) Howard (1914a)
Ellipsaria lineolata	
Lepomis cyanellus	Surber (1913) C. B. Wilson (1916)
Stizostedion canadense	Surber (1913)
Aplodinotus grunniens	Coker (1919) Coker et al. (1921) Howard (1914a) Howard and Anson (1922) C. B. Wilson (1916)
Proptera alata	
Aplodinotus grunniens	Howard (1913) C. B. Wilson (1916)

Proptera laevissima		
	Pomoxis annularis	Surber (1913) C. B. Wilson (1916)
	Aplodinotus grunniens	Coker and Surber (1911) Howard and Anson (1922) Surber (1912, 1913) C. B. Wilson (1916)
Truncilla donaciformis		
	Stizostedion canadense	Surber (1913) C. B. Wilson (1916)
	Aplodinotus grunniens	Howard (1913, 1914a) Surber (1912, 1913) C. B. Wilson (1916)
Truncilla truncata		
	Stizostedion canadense	C. B. Wilson (1916)
	Aplodinotus grunniens	C. B. Wilson (1916)

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In addition to the references cited in the present report, this bibliography brings together major (and numerous minor) references necessary for an understanding of the ecology of Upper Mississippi River fresh-water mussels. This list is not intended to (nor can it) contain all references to the subject. However, it does include all papers on Upper Mississippi mussels that were prepared by staff and associates of the Fairport, Iowa, mussel propagation laboratory of the (then) United States Bureau of Fisheries, plus many other citations concerning mussels, including such topics as symbiotic relationships (beyond host-parasite relationships), bioassay and other aspects of experimental physiology, taxon-specific identification, geographical and ecological ranges, etc.

The list is based principally on Fuller's (1974b) bibliography; however, not all items on Fuller's list are relevant to the present study, and the Academy has discovered further items that are included below. Compilation of this list was halted on 10 June 1978.

<u>Note</u>

Addenda to the Bibliography begin on page 394.

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FRESH-WATER MUSSELS (MOLLUSCA: BIVALVIA: UNIONIDAE) OF THE UPPE--ETC(U)
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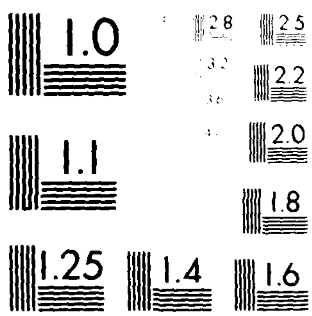
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ADDITIONS AND CORRECTIONS

In addition to the errata to the Bibliography (above), the following adjustments are in order.

Some of the information below causes changes in the taxa totals in Appendix C.

Page and, as useful, paragraph and line references are given. *Numeration of "paragraphs" on a given page starts with the first complete or fractional paragraph on that page.

Page 1:

This report's hyphenated elision of "fresh" and "water" in adjectival usage follows Webster's *Second [illegible] International Dictionary*.

Page 7, paragraph 2, lines 12-13 (and elsewhere in the report):

Corbicula manilensis (Philippi) should be called *C. fluminea* (Müller) (Mattice and Tilly, 1978).

Page 12, paragraph 4, lines 10-11:

For "Ortmann (1910b, 1911, 1912, 1919)" read "Ortmann (1909b, 1911, 1912, 1916, 1919)".

Page 13, paragraph 3, line 10:

For "Frontispiece" read "Frontispiece and page 79".

Pages 23-27:

Havlik's (1977a) account of Minnesota River mussels is relevant to this discussion.

Pages 26-27:

This study revealed *Corbicula fluminea* established in the St. Croix River (see above), Pool 9 (M. E. Havlik, personal communication), and Pool 19 (see below).

Page 28, paragraph 1, line 8 (and elsewhere in the report):

For "Lock and Dam" read "Locks and Dam".

Page 30, paragraph 5, line 6:

For "Dredge" read "Ponar dredge".

Page 32:

Amblema plicata and *Obliquaria reflexa* were recently found alive in Pool 3 (letter from S. L. H. Fuller to R. [illegible] Whiting, 25 May 1978).

Page 55, paragraph 3:

"From a total mass standpoint, agriculture is the major contributor of pollutional parameters in the Des Moines River" (Baumann et al., 1977). See, also, Wehrly (1977) and Baumann et al. (1978).

Page 63:

"This species [*Cyclonaias tuberculata*] was formerly more abundant in certain areas of the Upper Mississippi, but is now clammed out (Grier and Mueller, 1922-1923). These authors recorded this species from Lake Pepin and at Fairport, Iowa.

Pages 65-66:

For "Wartyback" read "Pimpleback".

Page 74:

"Many specimens [of *Proptera laevissima*] were found on sand bars" (Grier and Mueller, 1922-1923).

Pages 74-75:

The type locality of *Proptera alata* comprises Bayou Teche (in Louisiana) and St. Anthony Falls (Upper St. Anthony Falls Pool) (Call, 1895); "the concensus of opinion is that [this species] does not go much north of Davenport, Iowa" (Grier and Mueller, 1922-1923).

Pages 74-75 and 63-64:

Legal protection of [illegible] and [illegible], plus the latter's putative synonym [illegible] (see Exhibit [illegible]), as Nationally Endangered species was formalized in the [illegible], 41(115): [illegible], 14 June 1976.

Page [illegible]:

In the St. Francis River of Arkansas [illegible] was "commonly found in great numbers and of large size" ([illegible] al., 1893).

Pages [illegible]:

[illegible] (personal communication, [illegible] Department of Natural Resources) recently found a [illegible] in Pool [illegible].

Pages [illegible]:

The Principal Investigator's appreciation of population structure of [illegible] at Prairie du Chien was in part from shells in the [illegible] collection.

Pages [illegible]:

There is no evidence sufficient to support or refute [illegible] of the enigmatic [illegible] in a list of Upper Mississippi Basin naiades. Marshall ([illegible]) based [illegible] on a single, possibly deformed specimen that had been first described by Coker and Southall (1915). This shell resembles F. C. Baker's (1928) illustrations of some [illegible] teratological [illegible]. The soft-tissue morphology of [illegible] is unknown; its conchology suggests ascription to the Amblemini. The illustration by Coker and Southall was repeated by Marshall.

Page 112, paragraph 1-6, Page 113, paragraph 2:

[illegible] now replaces [illegible] and [illegible] genetic [illegible] ([illegible] Johnson, 1979).

Therefore, here and throughout the report, for "[illegible]" read "[illegible]".

Also, here and throughout the report, for "Johnson" read "R. I. Johnson".

Pages 118-121:

The following vernacular names can be added to those in Exhibit 5; insertion of these data into Exhibit 5 should follow the classification in Exhibit 1. The relevant authorities are Nordstrom et al. (1977), Perry (1979), and the *Federal Register*, 41(115): 24064, 14 June 1976.

Fusconaia flava -- Wabash Pigtoe

Proptera purpurata -- Western Heelsplitter

P. capax -- Fat Pocketbook Pearly Mussel

Leptodea leptodon -- Scale Shell

Lampsilis higginsi -- Higgin's Eye Orb Mucket (sic)
Higgin's Eye Pearly Mussel
Pink Mucket Pearly Mussel

Anodonta grandis -- Stout Floater

Page 319, paragraph 3, line 5

For "[illegible]" read "[illegible]"

Pages 320-332:

The order in which mussels are listed in Exhibit 323 essentially follows Fuller (1978b) and differs from the order in Exhibit 1.

Page 332:

Larval hosts of *Proptera purpurata* (see Appendix A) include *Aplodinotus grunniens* (Surber, 1913, 1915; C. B. Wilson, 1916).

Pages 334-390:

Complete copies of the following works are not available to the Principal Investigator, who has been unable to verify

omplete paginations: Baldwin (1973), Gale (1969), (1956), Mermilliod (1973), Pennak (1958), Stewart [illegible], rt (1975).

0 (and elsewhere in the Bibliography):

e citation "Economic Circular" (as in Shira, 1963) v should read "Department of Commerce Economic Circular".

7:

SACE (1973) should follow USACE (1974b).

he Principal Investigator has not seen the Illinois and rt analogs to USACE (1977a, 1977b, 1977c).

tterbach (1913-1916) was repaged and reprinted in 1966 University of Notre Dame Press, Notre Dame, Indiana (200).

95

he Principal Investigator has not seen the Minnesota and rt analogs to WPA (1938, 1939, 1941).

106

he Principal Investigator has not seen the Bureau of ies Document that corresponds to Wiebe (1927).

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